Engineering Data

United States
Radiator Corporation
Detroit, Michigan

A handy reference book of helpful information

No attempt has been made in this book to completely cover the lengthy subjects of combustion, heating, and ventilation engineering. Volumes have been published and are on sale which discuss every phase of heating science to an extent not possible in these pages.

Rather we have sought to select and compile the most practical and frequently used data, placing at the fingertips of the architect, heating engineer, and contractor a ready reference to the needed information for any usual installation of heating equipment.

Any of the information given can be relied upon. It has been procured from the latest authoritative sources and added to from the long experience of the Capitol Testing Laboratories.

The book contains, too, special data concerning particularly Capitol Boilers and United States Radiators, and also a telegraph code to facilitate the ordering of Boilers, Radiators, Specialties, Repairs and Parts.

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For Steam and Water Heating

BECAUSE of different conditions surrounding the installation of a heating apparatus, it is impossible to give any set rule that can be accepted, without modification, for all kinds of buildings to be heated. It is necessary to take into consideration all of the conditions in and around any building, and additions or deductions made to suit the requirements, no matter what rule may be used for figuring.

Nearly all rules are based on two to five pounds steam pressure and a temperature of 180 degrees for water, as indicated at the boiler when the outside temperature is at zero. When systems are designed for heating with a lower temperature at the boiler (vapor, vacuum, etc.) it is necessary to provide additional radiation in accordance with best practice for different systems.

Many contractors make the error of installing too little radiation. A little extra surface will give greater economy and insure a first-class working system, as well as a pleased owner. An apparatus of ample size can be regulated to give economy, which cannot be done if the apparatus is too small and requires forcing.

If *direct-indirect* radiation is to be used, *25 per cent* should be added to the radiation necessary for direct heating. If *indirect* radiation is to be used, *50 per cent* should be added to the amount of radiation necessary for direct heating. In schools, churches, etc., where ventilation is required, it is necessary to use some special rule for ventilating to obtain indirect surface. (Before determining the size of boiler required, all special forms of heating surface should be made the equivalent of direct radiation as shown on page 29.)

The amount of radiation computed for steam should be multiplied by 1.65 to determine the quantity of water radiation required.

The following rule has been found to give good results, but is not guaranteed. By using this rule and providing for additional radiation on the cold sides of building and making allowance for poor construction, loose-fitting windows, doors, etc., good results will be obtained.

For Steam and Water Heating

THIS rule is based on outside temperature at zero and inside temperature at 70 degrees for walls 12 inches thick. Corrections should be made for varying conditions as stated below:

C equals cubic contents in cubic feet.

W equals exposed wall in square feet.

G equals glass (windows and doors) square feet.

R equals radiation in square feet.

Steam

$$\frac{(6\ C)+(80\ W)+(300\ G)}{1000}=R$$

Water

$$\frac{(6\ C)+(80\ W)+(300\ G)}{600}=R$$

EXAMPLE.—A given room has 50 square feet of glass, 220 square feet wall and 1800 cubic feet space. Substituting the figures in place of letters in formula above:

$$\frac{(6\times1800)+(80\times220)+(300\times50)}{1000}=$$

$$\frac{10800+17600+15000}{1000}=43.4 \text{ square feet steam radiation.}$$

$$\frac{10800+17600+15000}{600}=72.3 \text{ square feet hot water radiation.}$$

Corrections for Varying Temperatures and Local Conditions

Add one per cent of radiation for each degree below zero outside or above 70 degrees inside. Subtract one per cent for each degree above zero outside or below 70 degrees inside.

Residences

For Halls and Dining Rooms, use 10 C.

For Bath Rooms, use 20 C.

For Bed Rooms, use 5 C.

Exposures

Rooms on sides of prevailing winds should have radiation increased 10 per cent. Walls exposed to unheated rooms and spaces use 40 W.

For Steam and Water Heating
Heat Loss Through Walls

Rule based on 12-inch Brick Wall or good Frame Construction. For other types of construction use the following factors:

8-inch Brick Wall	120 W
12-inch Brick Wall	80 W
16-inch Brick Wall	70 W
20-inch Brick Wall	60 W
9-inch Brick Wall, 2-inch hollow tile with cement mortar	85 W
8-inch Brick Wall, hollow brick furring, plaster inside	85 W
12-inch Brick Wall, hollow brick furring, plaster inside	70 W
16-inch Brick Wall, hollow brick furring, plaster inside	60 W
20-inch Brick Wall, hollow brick furring, plaster inside	55 W
28-inch Brick Wall, hollow brick furring, plaster inside	40 W
Brick, sheathing, air space, lath, plaster	50 W
Brick, sheathing, air space, back plaster, plaster	40 W
2-inch Hollow Tile, ½-inch plaster both sides	115 W
4-inch Hollow Tile, ½-inch plaster both sides	95 W
6-inch Hollow Tile, ½-inch plaster both sides	80 W
12-inch Hollow Tile, ½-inch plaster both sides	75 W
20-inch Hollow Tile, ½-inch plaster both sides	60 W
Double Fireproof Tile, plaster both sides, air space between	65 W
12-inch Concrete—Sandstone facing	130 W
20-inch Concrete—Sandstone facing	110 W
12-inch Sandstone	135 W
16-inch Sandstone	120 W
12-inch Sandstone with 2-inch terra cotta or wood furring and plaster	115 W
16-inch Sandstone with 2-inch terra cotta or wood furring and plaster	100 W
12-inch Limestone	145 W
16-inch Limestone	125 W
12-inch Limestone, 2-inch terra cotta or wood furring and plaster	125 W
16-inch Limestone, 2-inch terra cotta or wood furring and plaster	105 W
12-inch Granite or Marble	135 W
18-inch Granite or Marble	115 W
12-inch Granite, 2-inch terra cotta or wood furring and plaster	115 W
18-inch Granite, 2-inch terra cotta or wood furring and plaster	100 W
Frame wall (plaster, lath, stud, clapboard)	140 W
Frame wall (plaster, lath, stud, sheathing, clapboard)	80 W
Frame wall (plaster, lath, stud, sheathing, paper, clapboard)	65 W
Ordinary stud partition, plaster both sides	100 W
Ordinary stud partition, plaster one side	180 W

Double 1-inch board, 2 inches sawdust between	37 W
Double 1-inch board, 4 inches sawdust between	26 W
Double 1-inch board, 6 inches sawdust between	17 W
Plain wood wall ¾-inch	200 W
Plain wood wall 1-inch	170 W
Plain wood wall 2-inch	125 W
Plain wood wall 4-inch	85 W
Double pine boards, paper between ½-inch boards	95 W
Double pine boards, paper between 1-inch boards	70 W
Double pine boards, paper between 2-inch boards	45 W
Channel iron partition, wire lath, plaster both sides	100 W
Channel iron partition, asbestos filling	60 W
Corrugated iron with ½-inch tongue and groove board	130 W
Corrugated iron with 1-inch tongue and groove board	105 W
Corrugated iron with 2-inch tongue and groove board	75 W
Unlined corrugated iron	430 W
Unlined sheet iron	350 W
Sheet iron on ½-inch pine facing	145 W
Sheet iron on 1-inch pine facing	115 W
Sheet iron on 2-inch pine facing	80 W

Solid cement and concrete block when plastered directly on wall should be figured same as 8-inch brick. Same, with space between wall and plaster, as 12-inch brick. Brick veneer same as 12-inch brick.

Glass

Double windows	140 G
Skylights, same as windows, double or single.	
Plate glass	250 G
Monitor windows, single glass	310 G

Roofs and Floors

Tin or copper roof on 1-inch boards	130 W
Shingle roof	95 W
Dirt floor	60 W
Concrete or cement on dirt	90 W
Wood on cement floor	35 W

Churches, Auditoriums and Factories

When churches, auditoriums and factories with high ceilings are heated continuously, the radiation as computed by the rule may be decreased, in accordance with the factors indicated below.

Contents in Cubic Feet	Factor
30,000 to 50,000	.9
50,000 to 70,000	.85

Churches, Auditoriums and Factories (Continued)

Contents in Cubic Feet	Factor
70,000 to 90,000	.8
90,000 to 110,000	.75
Over 110,000	.7

For garages and other buildings, having a large number of air changes per hour, additional radiation should be provided. Use from 15 to 30C.

Competent authorities recommend that in order to reduce the time required to warm buildings which are heated intermittently, the radiation as computed by reputable rules should be increased 10 to 30% depending upon the interval between heating and the exposure of the building.

Usual Inside Temperature Specified

Public Buildings	68°-72°F.
Factories	65°F.
Machine Shops	60°-65°F.
Foundries, Boiler Shops, etc.	50°-60°F.
Residences	70°F.
Bath Rooms	85°F.
Schools	70°F.
Hospitals	72°-75°F.
Paint Shops	80°F.

Cubical Contents of Rooms

CEILING 8½ FEET HIGH

Examples: Cubical contents of room 10 x 14 x 8½ = 1190 cu. ft.

Cubical contents of large rooms such as 22½ x 24 x 8½ = cubical contents of two rooms 10½ x 24 x 8½ and 12 x 24 x 8½ = 2142 + 2448 = 4590 cu. ft.

8½ FT. CEILING

WIDTH \ LENGTH	4	4½	5	5½	6	6½	7	7½	8	8½	9	9½	10	10½	11	11½	12	12½	13	13½	14	14½	15	16	17	18	19	20	21	22	23	24	25
4	136	153	170	187	204	221	238	255	272	289	306	323	340	357	374	391	408	425	442	459	476	493	510	544	578	612	646	680	714	748	782	816	850
4½	153	172	191	210	230	249	268	287	306	325	345	363	382	402	421	440	459	478	497	516	536	555	574	612	650	689	727	765	803	842	880	918	956
5	170	191	212	234	255	276	298	319	340	361	383	404	425	446	468	489	510	531	553	574	595	616	638	680	722	765	807	850	893	935	978	1020	1063
5½	187	210	234	257	281	304	327	351	374	397	421	444	468	491	514	538	561	584	608	631	655	678	701	748	795	842	888	935	982	1029	1075	1122	1169
6	204	230	255	281	306	332	357	383	408	434	459	485	510	536	561	587	613	638	663	689	714	740	765	816	867	918	969	1020	1071	1122	1173	1224	1275
6½	221	249	276	304	332	359	387	414	442	470	497	525	553	580	608	635	662	691	718	746	774	801	829	884	939	995	1050	1105	1160	1216	1271	1326	1381
7	238	268	298	327	357	387	417	446	476	506	536	565	595	625	655	684	714	744	774	803	833	863	893	952	1012	1071	1131	1190	1250	1309	1369	1428	1488
7½	255	287	319	351	383	414	446	478	510	542	574	606	638	669	701	733	765	797	829	861	893	924	956	1020	1084	1148	1211	1275	1339	1403	1466	1530	1594
8	272	306	340	374	408	442	476	510	544	578	612	646	680	714	748	782	816	850	884	918	952	986	1020	1088	1156	1224	1292	1360	1428	1496	1564	1632	1700
8½	289	325	361	397	434	470	506	542	578	614	650	686	723	759	795	831	867	903	939	975	1012	1048	1084	1156	1228	1301	1373	1445	1517	1590	1662	1734	1806
9	306	345	383	421	459	497	536	574	612	650	689	727	765	803	842	880	918	956	995	1033	1071	1109	1148	1224	1301	1377	1454	1530	1607	1683	1760	1836	1913
9½	323	363	404	444	485	525	565	606	646	686	727	767	808	848	888	929	969	1009	1050	1090	1131	1171	1211	1292	1373	1454	1534	1615	1696	1777	1857	1938	2019
10	340	382	425	468	510	553	595	638	680	723	765	808	850	893	935	978	1020	1063	1105	1148	1190	1233	1275	1360	1445	1530	1615	1700	1785	1870	1955	2040	2125
10½	357	402	446	491	536	580	625	669	714	759	803	848	893	937	982	1026	1071	1116	1160	1205	1250	1294	1339	1428	1517	1607	1696	1785	1874	1964	2053	2142	2231
11	374	421	468	514	561	608	655	701	748	795	842	888	935	982	1029	1075	1122	1169	1216	1262	1309	1356	1403	1496	1590	1683	1777	1870	1964	2057	2151	2244	2338
11½	391	440	489	538	587	635	684	733	782	831	880	929	978	1026	1075	1124	1173	1222	1271	1320	1369	1418	1466	1564	1662	1760	1857	1955	2053	2151	2248	2346	2444
12	408	459	510	561	612	663	714	765	816	867	918	969	1020	1071	1122	1173	1224	1275	1326	1377	1428	1479	1530	1632	1734	1836	1938	2040	2142	2244	2346	2448	2550
13	442	497	553	608	663	718	774	829	884	939	995	1050	1105	1160	1216	1271	1326	1381	1437	1492	1547	1602	1658	1768	1879	1989	2100	2210	2321	2431	2542	2652	2763
14	476	536	595	655	714	774	833	893	952	1012	1071	1131	1190	1250	1309	1369	1428	1488	1547	1607	1666	1726	1785	1904	2023	2142	2261	2380	2499	2618	2737	2856	2975
15	510	574	638	701	765	829	893	956	1020	1084	1148	1211	1275	1339	1403	1466	1530	1594	1658	1721	1785	1849	1913	2040	2168	2295	2423	2550	2678	2805	2933	3060	3188
	4	4½	5	5½		6½	7	7½	8	8½	9	9½	10	10½	11	11½	12	12½	13	13½	14	14½	15	16	17	18	19	20	21	22	23	24	25

Cubical Contents of Rooms

CEILING 9 FEET HIGH

Example: Cubical contents of room 10 x 14 x 9=1260 cu. ft.
Cubical contents of large rooms such as 17½ x 20 x 9=cubical contents of two rooms 8½ x 20 x 9 and 9 x 20 x 9=1530+1620=3150 cu. ft.

9 FT. CEILING

LENGTH (across) / **WIDTH** (down)

	4	4½	5	5½	6	6½	7	7½	8	8½	9	9½	10	10½	11	11½	12	12½	13	13½	14	14½	15	16	17	18	19	20	21	22	23	24	25
4	144	162	180	198	216	234	252	270	288	306	324	342	360	378	396	414	432	450	468	486	504	522	540	576	612	648	684	720	756	792	828	864	900
4½	162	182	203	223	243	263	284	304	324	344	365	385	405	425	446	466	486	506	527	547	567	587	608	648	689	729	770	810	851	891	932	972	1013
5	180	203	225	248	270	293	315	338	360	383	405	428	450	473	495	518	540	563	585	608	630	653	675	720	765	810	855	900	945	990	1035	1080	1125
5½	198	223	248	272	297	322	347	371	396	421	446	470	495	520	545	569	594	619	644	668	693	718	743	792	842	891	941	990	1040	1089	1139	1188	1238
6	216	243	270	297	324	351	378	405	432	459	486	513	540	567	594	621	648	675	702	729	756	783	810	864	918	972	1026	1080	1134	1188	1242	1296	1350
6½	234	263	293	322	351	380	410	439	468	497	527	556	585	614	644	673	702	731	761	790	819	848	878	936	995	1053	1112	1170	1229	1287	1346	1404	1463
7	252	284	315	347	378	410	441	473	504	536	567	599	630	662	693	725	756	788	819	851	882	914	945	1008	1071	1134	1197	1260	1323	1386	1449	1512	1575
7½	270	304	338	371	405	439	473	506	540	574	608	641	675	709	743	776	810	844	878	911	945	979	1013	1080	1148	1215	1283	1350	1418	1485	1553	1620	1688
8	288	324	360	396	432	468	504	540	576	612	648	684	720	756	792	828	864	900	936	972	1008	1044	1080	1152	1224	1296	1368	1440	1512	1584	1656	1728	1800
8½	306	344	383	421	459	497	536	574	612	650	689	727	765	803	842	880	918	956	995	1033	1071	1109	1148	1224	1301	1377	1454	1530	1607	1683	1760	1836	1913
9	324	365	405	446	486	527	567	608	648	689	729	770	810	851	891	932	972	1013	1053	1094	1134	1175	1215	1296	1377	1458	1539	1620	1701	1782	1863	1944	2025
9½	342	385	428	470	513	556	599	641	684	727	770	812	855	898	940	983	1026	1069	1111	1154	1197	1240	1282	1368	1453	1539	1625	1710	1796	1881	1967	2052	2138
10	360	405	450	495	540	585	630	675	720	765	810	855	900	945	990	1035	1080	1125	1170	1215	1260	1305	1350	1440	1530	1620	1710	1800	1890	1980	2070	2160	2250
10½	378	425	473	520	567	614	662	709	756	803	851	898	945	992	1040	1087	1134	1181	1229	1276	1323	1370	1418	1512	1607	1701	1796	1890	1985	2079	2174	2268	2363
11	396	446	495	545	594	644	693	743	792	842	891	940	990	1040	1089	1139	1188	1238	1287	1337	1386	1436	1485	1584	1683	1782	1881	1980	2079	2178	2277	2376	2475
11½	414	466	518	569	621	673	725	776	828	880	932	983	1035	1087	1139	1190	1242	1294	1346	1397	1449	1501	1553	1656	1760	1863	1967	2070	2174	2277	2381	2484	2588
12	432	486	540	594	648	702	756	810	864	918	972	1026	1080	1134	1188	1242	1296	1350	1404	1458	1512	1566	1620	1728	1836	1944	2052	2160	2268	2376	2484	2592	2700
13	468	527	585	644	702	761	819	878	936	995	1053	1111	1170	1229	1287	1346	1404	1463	1521	1580	1638	1697	1755	1872	1989	2106	2223	2340	2457	2574	2691	2808	2925
14	504	567	630	693	756	819	882	945	1008	1071	1134	1197	1260	1323	1386	1449	1512	1575	1638	1701	1764	1827	1890	2016	2142	2268	2394	2520	2646	2772	2898	3024	3150
15	540	608	675	743	810	878	945	1013	1080	1148	1215	1282	1350	1418	1485	1553	1620	1688	1755	1823	1890	1958	2025	2160	2295	2430	2565	2700	2835	2970	3105	3240	3375
	4	4½	5	5½	6	6½	7	7½	8	8½	9	9½	10	10½	11	11½	12	12½	13	13½	14	14½	15	16	17	18	19	20	21	22	23	24	25

Cubical Contents of Rooms

CEILING 9½ FEET HIGH

Example: Cubical contents of room 8 x 14½ x 9½ = 1102 cu. ft.
Cubical contents of large rooms such as 25 x 24 x 9½ = cubical contents of two rooms 15 x 24 x 9½ and 10 x 24 x 9½ = 3420 + 2280 = 5700 cu. ft.

9½ FT. CEILING

LENGTH

WIDTH	4	4½	5	5½	6	6½	7	7½	8	8½	9	9½	10	10½	11	11½	12	12½	13	13½	14	14½	15	16	17	18	19	20	21	22	23	24	25
4	152	171	190	209	228	247	266	285	304	323	342	361	380	399	418	437	456	475	494	513	532	551	570	608	646	684	722	760	798	836	874	912	950
4½	171	192	213	235	256	277	299	320	342	363	384	406	427	448	470	491	513	534	555	577	598	610	641	684	726	769	812	855	897	940	983	1026	1069
5	190	213	237	261	285	308	332	356	380	403	427	451	475	498	522	547	570	593	617	641	665	688	712	760	807	855	902	950	997	1045	1092	1140	1187
5½	209	235	261	287	313	339	365	391	418	444	470	496	522	548	574	600	627	653	679	705	731	757	783	836	888	940	993	1045	1097	1149	1201	1254	1306
6	228	256	285	313	342	370	399	427	456	484	513	541	570	598	627	655	684	712	741	769	798	826	855	912	969	1026	1083	1140	1197	1254	1311	1368	1425
6½	247	277	308	339	370	401	432	463	494	524	555	586	617	648	679	710	741	771	802	833	864	895	926	988	1049	1111	1173	1235	1296	1358	1420	1482	1543
7	266	299	332	365	399	432	465	498	532	565	598	631	665	698	731	764	798	831	864	897	931	964	997	1064	1130	1197	1263	1330	1396	1463	1529	1596	1662
7½	285	320	356	391	427	463	498	534	570	605	641	676	712	748	783	819	855	890	926	961	997	1033	1068	1140	1211	1282	1353	1425	1496	1567	1638	1710	1781
8	304	342	380	418	456	494	532	570	608	646	684	722	760	798	836	874	912	950	988	1026	1064	1102	1140	1216	1292	1368	1444	1520	1596	1672	1748	1824	1900
8½	323	363	403	444	484	524	565	605	646	686	726	767	807	847	888	928	969	1009	1049	1090	1130	1170	1211	1292	1372	1453	1534	1615	1695	1776	1857	1938	2018
9	342	384	427	470	513	555	598	641	684	726	767	812	855	897	940	982	1026	1068	1111	1154	1197	1239	1282	1368	1453	1539	1624	1710	1795	1881	1967	2052	2137
9½	361	406	451	496	541	586	631	676	722	767	812	857	902	947	992	1038	1083	1128	1173	1218	1263	1308	1353	1444	1534	1624	1714	1805	1895	1985	2075	2166	2256
10	380	427	475	522	570	617	665	712	760	807	855	902	950	997	1045	1092	1140	1187	1235	1282	1330	1377	1425	1520	1615	1710	1805	1900	1995	2090	2185	2280	2375
10½	399	448	498	548	598	648	698	748	798	847	897	947	997	1047	1097	1147	1197	1246	1296	1346	1396	1446	1496	1596	1695	1795	1895	1995	2094	2194	2294	2394	2493
11	418	470	522	574	627	679	731	783	836	888	940	992	1045	1097	1149	1201	1254	1306	1358	1410	1463	1515	1567	1672	1776	1881	1986	2090	2194	2299	2403	2508	2612
11½	437	491	547	600	655	710	764	819	874	928	982	1038	1092	1147	1201	1256	1311	1365	1420	1474	1529	1584	1638	1748	1857	1966	2075	2185	2295	2403	2512	2622	2731
12	456	513	570	627	684	741	798	855	912	969	1026	1083	1140	1197	1254	1311	1368	1425	1482	1539	1596	1653	1710	1824	1938	2052	2166	2280	2394	2507	2622	2736	2850
13	494	555	617	679	741	802	864	926	988	1049	1111	1173	1235	1296	1358	1420	1482	1543	1605	1667	1729	1790	1852	1976	2099	2223	2346	2470	2593	2717	2840	2964	3087
14	532	598	665	731	798	864	931	997	1064	1130	1197	1263	1330	1396	1463	1529	1596	1663	1729	1795	1862	1928	1995	2128	2261	2394	2527	2660	2793	2926	3059	3192	3325
15	570	641	712	783	855	926	997	1068	1140	1211	1282	1353	1425	1496	1567	1638	1710	1781	1852	1923	1995	2066	2137	2280	2422	2565	2707	2850	2992	3135	3277	3420	3652
	4	4½	5	5½	6	6½	7	7½	8	8½	9	9½	10	10½	11	11½	12	12½	13	13½	14	14½	15	16	17	18	19	20	21	22	23	24	25

Cubical Contents of Rooms

CEILING 10 FEET HIGH

Example: Cubical contents of room 10½ x 12½ x 10=1313 cu. ft.
Cubical contents of large rooms such as 17½ x 20 x 10=cubical contents of two rooms 10 x 20 x 10 and 7½ x 20 x 10=2000+1500=3500 cu. ft.

10 FT. CEILING

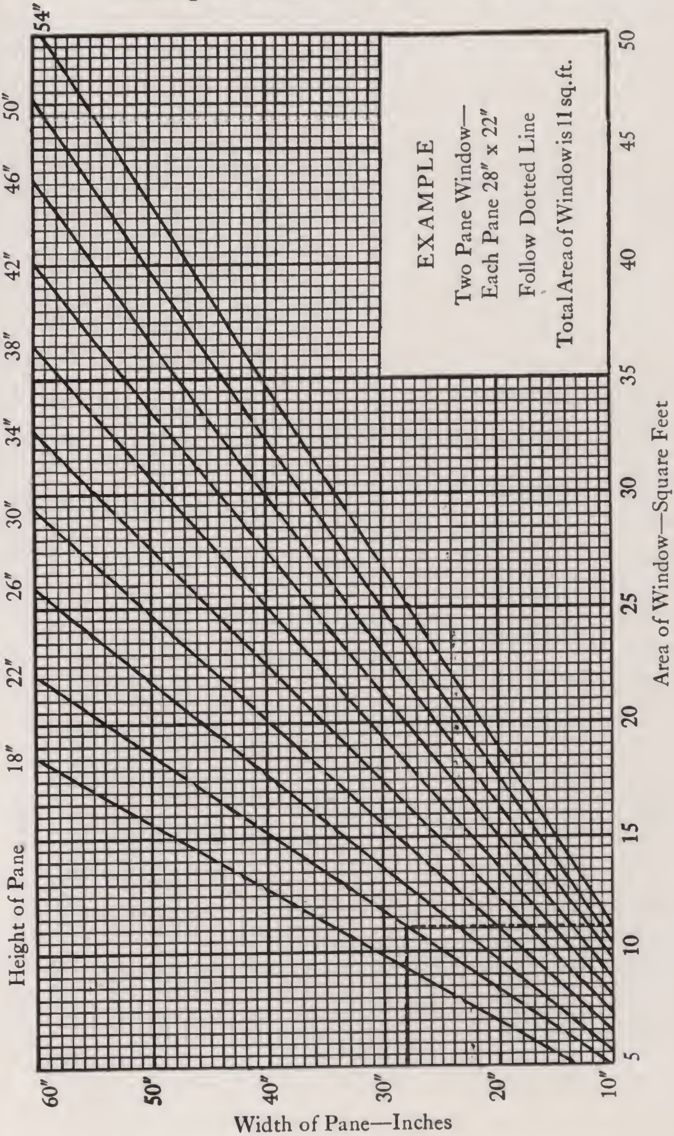
WIDTH \ LENGTH	4	4½	5	5½	6	6½	7	7½	8	8½	9	9½	10	10½	11	11½	12	12½	13	13½	14	14½	15	16	17	18	19	20	21	22	23	24	25
4	160	180	200	220	240	260	280	300	320	340	360	380	400	420	440	460	480	500	520	540	560	580	600	640	680	720	760	800	840	880	920	960	1000
4½	180	203	225	248	270	293	315	338	360	383	405	428	450	473	495	518	540	563	585	608	630	653	675	720	765	810	855	900	945	990	1035	1080	1125
5	200	225	250	275	300	325	350	375	400	425	450	475	500	525	550	575	600	625	650	675	700	725	750	800	850	900	950	1000	1050	1100	1150	1200	1250
5½	220	248	275	303	330	358	385	413	440	468	495	523	550	578	605	633	660	688	715	743	770	798	825	880	935	990	1045	1100	1155	1210	1265	1320	1375
6	240	270	300	330	360	390	420	450	480	510	540	570	600	630	660	690	720	750	780	810	840	870	900	960	1020	1080	1140	1200	1260	1320	1380	1440	1500
6½	260	293	325	358	390	423	455	488	520	553	585	618	650	683	715	748	780	813	845	878	910	943	975	1040	1105	1170	1235	1300	1365	1430	1495	1560	1625
7	280	315	350	385	420	455	490	525	560	595	630	665	700	735	770	805	840	875	910	945	980	1015	1050	1120	1190	1260	1330	1400	1470	1540	1610	1080	1750
7½	300	338	375	413	450	488	525	563	600	638	675	713	750	788	825	863	900	938	975	1013	1050	1088	1125	1200	1275	1350	1425	1500	1575	1650	1725	1800	1875
8	320	360	400	440	480	520	560	600	640	680	720	760	800	840	880	920	960	1000	1040	1080	1120	1160	1200	1280	1360	1440	1520	1600	1680	1760	1840	1920	2000
8½	340	383	425	468	510	553	595	638	680	723	765	808	850	893	935	978	1020	1063	1105	1148	1190	1233	1275	1360	1445	1530	1615	1700	1785	1870	1955	2040	2125
9	360	405	450	495	540	585	630	675	720	765	810	855	900	945	990	1035	1080	1125	1170	1215	1260	1305	1350	1440	1530	1620	1710	1800	1890	1980	2070	2160	2250
9½	380	428	475	523	570	618	665	713	760	808	855	903	950	998	1045	1093	1140	1188	1235	1283	1330	1378	1425	1520	1615	1710	1805	1900	1995	2090	2185	2280	2375
10	400	450	500	550	600	650	700	750	800	850	900	950	1000	1050	1100	1150	1200	1250	1300	1350	1400	1450	1500	1600	1700	1800	1900	2000	2100	2200	2300	2400	2500
10½	420	473	525	578	630	683	735	788	840	893	945	998	1050	1103	1155	1208	1260	1313	1365	1418	1470	1523	1575	1680	1785	1890	1995	2100	2205	2310	2415	2520	2625
11	440	495	550	605	660	715	770	825	880	935	990	1045	1100	1155	1210	1265	1320	1375	1430	1485	1540	1595	1650	1760	1870	1980	2090	2200	2310	2420	2530	2640	2750
11½	460	518	575	633	690	748	805	863	920	978	1035	1093	1150	1208	1265	1323	1380	1438	1495	1553	1610	1668	1725	1840	1955	2070	2185	2300	2415	2530	2645	2760	2875
12	480	540	600	660	720	780	840	900	960	1020	1080	1140	1200	1260	1320	1380	1440	1500	1560	1620	1680	1740	1800	1920	2040	2160	2280	2400	2520	2640	2760	2880	3000
13	520	585	650	715	780	845	910	975	1040	1105	1170	1235	1300	1365	1430	1495	1560	1625	1690	1755	1820	1885	1950	2080	2210	2340	2470	2600	2730	2860	2990	3120	3250
14	560	630	700	770	840	910	980	1050	1120	1190	1260	1330	1400	1470	1540	1610	1680	1750	1820	1890	1960	2030	2100	2240	2380	2520	2660	2800	2940	3080	3220	3360	3500
15	600	675	750	825	900	975	1050	1125	1200	1275	1350	1425	1500	1575	1650	1725	1800	1875	1950	2025	2100	2175	2250	2400	2550	2700	2850	3000	3150	3300	3450	3600	3750
	4	**4½**	**5**	**5½**	**6**	**6½**	**7**	**7½**	**8**	**8½**	**9**	**9½**	**10**	**10½**	**11**	**11½**	**12**	**12½**	**13**	**13½**	**14**	**14½**	**15**	**16**	**17**	**18**	**19**	**20**	**21**	**22**	**23**	**24**	**25**

SQUARE FEET OF WALL SURFACE

Running Feet of Wall	CEILING HEIGHTS—FEET											
	8	8½	9	9½	10	10½	11	11½	12	13	14	15
6	48	51	54	57	60	63	66	69	72	78	84	90
6½	52	55	59	62	65	68	72	75	78	85	91	98
7	56	60	63	67	70	74	77	81	84	91	98	105
7½	60	64	68	72	75	79	83	86	90	98	105	113
8	64	68	72	76	80	84	88	92	96	104	112	120
8½	68	72	77	81	85	89	94	98	102	111	119	128
9	72	76	81	86	90	94	99	104	108	117	126	135
9½	76	81	86	90	95	100	105	109	114	124	133	143
10	80	85	90	95	100	105	110	115	120	130	140	150
10½	84	89	95	100	105	110	116	121	126	137	147	158
11	88	94	99	105	110	116	121	127	132	143	154	165
11½	92	98	104	109	115	121	127	132	138	150	161	173
12	96	102	108	114	120	126	132	138	144	156	168	180
12½	100	106	113	119	125	131	138	144	150	163	175	188
13	104	111	117	123	130	137	143	150	156	169	182	195
13½	108	115	122	129	135	142	149	155	162	176	189	203
14	112	119	126	133	140	147	154	161	168	182	196	210
14½	116	123	131	138	145	152	160	167	174	189	203	218
15	120	128	135	143	150	158	165	173	180	195	210	225
15½	124	132	140	147	155	163	171	178	186	202	217	233
16	128	136	144	152	160	168	176	184	192	208	224	240
16½	132	140	149	157	165	173	182	190	198	215	231	248
17	136	145	153	162	170	179	187	196	204	221	238	255
17½	140	149	158	166	175	184	193	201	210	228	245	263
18	144	153	162	171	180	189	198	207	216	234	252	270
19	152	162	171	181	190	200	209	219	228	247	266	285
20	160	170	180	190	200	210	220	230	240	260	280	300
21	168	179	189	200	210	221	231	242	252	273	294	315
22	176	187	198	209	220	231	242	253	264	286	308	330
23	184	196	207	218	230	242	253	264	276	299	322	345
24	192	204	216	228	240	252	264	276	288	312	336	360
25	200	213	225	238	250	263	275	288	300	325	350	375
26	208	221	234	247	260	273	286	299	312	338	364	390
27	216	230	243	257	270	284	297	311	324	351	378	405
28	224	238	252	266	280	294	308	322	336	364	392	420
29	232	247	261	276	290	305	319	334	348	377	406	435
30	240	255	270	285	300	315	330	345	360	390	420	450
31	248	264	279	295	310	326	341	357	372	403	434	465
32	256	272	288	304	320	336	352	368	384	416	448	480

FULL AREA OF TWO-PANE WINDOWS

Giving the Total Area Including Sash



Compiled from Records of the U. S. Weather Bureau

STATE	CITY	Average Temperature Oct. 1st-May 1st.	Lowest Temperature	Average Wind Velocity Dec. Jan., Feb. Miles per Hr.	Direction of Prevailing Wind Dec., Jan. Feb.
Ala.	Mobile	57.7	– 1	8.3	N
	Birmingham	53.9	–10	8.6	N
Ariz.	Phoenix	59.5	16	3.9	E
	Flagstaff	34.9	–25	6.7	SW
Ark.	Fort Smith	49.5	–15	8.0	E
	Little Rock	51.6	–12	9.9	NW
Calif.	San Francisco	54.3	29	....	N
	Los Angeles	58.6	28	....	NE
Col.	Denver	39.3	–29	7.4	S
	Grand Jct	39.2	–16	5.6	SE
Conn.	New Haven	38.0	–14	9.3	N
D. C.	Washington	43.2	–15	7.3	NW
Fla.	Jacksonville	61.9	10	8.2	NE
Ga.	Atlanta	51.4	– 8	11.8	NW
	Savannah	58.4	8	8.3	NW
Idaho	Lewiston	42.5	–13	4.7	E
	Pocatello	36.4	–20	9.3	SE
Ill.	Chicago	36.4	–23	17	SW
	Springfield	39.9	–24	10.2	NW
Ind.	Indianapolis	40.2	–25	11.8	S
	Evansville	44.1	–15	8.4	S
Iowa	Dubuque	33.9	–32	6.1	NW
	Sioux City	32.1	–35	12.2	NW
Kan.	Concordia	38.9	–25	7.3	N
	Dodge City	40.2	–26	10.4	NW
Ky.	Louisville	45.2	–20	9.3	SW
La.	New Orleans	61.5	7	9.6	N
	Shreveport	56.2	– 5	7.7	SE
Me.	Eastport	31.1	–23	13.8	W
	Portland	33.6	–17	10.1	NW
Md.	Baltimore	43.6	– 7	7.2	NW
Mass.	Boston	37.6	–13	11.7	W
Mich.	Alpena	29.1	–27	11.3	W
	Detroit	35.4	–24	13.1	SW
	Marquette	27.6	–27	11.4	NW
Minn.	Duluth	25.1	–41	11.1	SW
	Minneapolis	29.6	–33	11.5	NW
Miss.	Vicksburg	56.0	– 1	7.6	SE
Mo.	St. Joseph	40.3	–24	9.1	NW
	St. Louis	43.3	–22	11.8	NW
	Springfield	43.0	–29	11.3	SE
Mont.	Billings	34.7	–49	....	W
	Havre	27.7	–57	8.7	SW
Neb.	Lincoln	37.0	–29	10.9	N
	North Platte	34.6	–35	9.0	W

STATE	CITY	Average Temperature Oct. 1st-May 1st	Lowest Temperature	Average Wind Velocity Dec. Jan. Feb. Miles per Hr.	Direction of Prevailing Wind Dec. Jan. Feb.
Nev.	Tonopah	39.6	− 7	9.9	SE
	Winnemucca	37.9	−28	9.5	NE
N. H.	Concord	33.4	−35	6.0	NW
N. J.	Atlantic City	41.6	− 7	10.6	NW
N. Y.	Albany	35.1	−24	7.9	S
	Buffalo	34.7	−14	17.7	W
	New York	40.3	− 6	13.3	NW
N. M.	Santa Fe	38.0	−13	7.3	NE
N. C.	Raleigh	49.7	− 2	7.3	SW
	Wilmington	53.1	5	8.9	SW
N. D.	Bismarck	24.5	−45	....	NW
	Devil's Lake	18.9	−44	11.4	W
Ohio	Cleveland	36.9	−17	14.5	SW
	Columbus	39.9	−20	9.3	SW
Okla.	Oklahoma City	48.0	−17	12.0	N
Ore.	Baker	34.1	−20	6.0	SE
	Portland	45.9	− 2	6.5	S
Pa.	Philadelphia	41.9	− 6	11.0	NW
	Pittsburgh	40.8	−20	13.7	NW
R. I.	Providence	37.6	− 9	14.6	NW
S. C.	Charleston	56.9	7	11.0	N
	Columbia	53.7	− 2	8.0	NE
S. D.	Huron	28.1	−43	11.5	NW
	Rapid City	32.3	−34	7.5	W
Tenn.	Knoxville	47.0	−16	6.5	SW
	Memphis	50.9	− 9	9.6	NW
Tex.	El Paso	53.0	− 2	10.5	NW
	Fort Worth	54.7	− 8	11.0	NW
	San Antonio	60.7	4	8.2	N
Utah.	Modena	38.1	−24	8.9	W
	Salt Lake City	40.0	−20	4.9	SE
Vt.	Burlington	29.3	−27	12.9	S
Va.	Norfolk	49.1	2	9.0	N
	Lynchburg	45.2	− 7	5.2	NW
	Richmond	47.4	− 3	7.4	S
Wash.	Seattle	45.3	3	9.1	SE
	Spokane	37.5	−30	....	SW
W. Va.	Elkins	38.8	−21	4.8	W
	Parkersburg	41.9	−27	6.6	S
Wis.	Green Bay	28.6	−36	12.8	SW
	La Crosse	31.2	−43	5.6	NW
	Milwaukee	33.0	−25	11.7	W
Wyo.	Sheridan	31.0	−45	5.3	NW
	Lander	28.9	−36	3.0	NE

Setting Indirect Radiators

INDIRECT Radiators are used for ventilating and for foot warmers, and for those places where radiators in the rooms would be objectionable.

In setting indirect stacks, care should be taken to see that both sides and ends come in contact with casings to prevent the passage of air other than directly through the radiator. A space of at least ten inches should be provided above the top and six to eight inches below the bottom of radiator for free circulation of air. The fresh air should be delivered to under side of radiator at opposite end from which the warm air is taken.

Satisfactory results are obtained by placing the register on the inside wall or near to an inside wall, when desired in floor. The warm air should be delivered to register from the top at one end of radiator.

Because the cold air comes in contact with Indirect Radiators, their cooling power is greatly increased over direct radiation and varies with the temperature, volume and velocity of air entering the stack.

Under ordinary conditions in house heating, indirect radiation will give off 400 to 650 B.T.U. for steam or 240 to 390 B.T.U. for water per square foot per hour. In ventilating school or other public buildings by gravity the above can be increased from one-half to two times. It is good engineering practice, when possible, to connect indirect stacks with a separate flow and return main from boiler.

The following table will be found of much value when designing or installing Indirect Radiators.

Sizes of Air Ducts and Registers for Indirect Heating

Square Feet of Radiation	Cold Air Duct to Stack		Warm Air Duct		Registers		
	For First Floors Square Inches	For Upper Floors Square Inches	For First Floors Square Inches	For Upper Floors Square Inches	For First Floors Inches	For Upper Floors Inches	Tappings Inches
40	40	35	60	40	10x12	8x10	1 x ¾
50	50	40	75	50	10x12	8x10	1 x ¾
60	60	45	90	60	10x14	8x12	1¼x1
70	70	50	105	70	12x15	10x12	1¼x1
80	80	60	120	80	12x15	10x12	1¼x1
90	90	70	135	90	12x19	10x14	1½x1¼
100	100	75	150	100	12x19	12x15	1½x1¼
120	110	90	170	110	16x16	12x15	1½x1¼
140	120	105	190	120	16x18	12x18	2 x1½
160	130	120	210	130	16x20	12x20	2 x1½

For heat losses from Indirect Radiators, see top of page 17.

For air space between sections, see page 22 of Radiator Catalogue.

Standard Pin

Cu. Ft. of Air Passing per Sq. Ft. of Radiation	Increase in Temperature of the Air Passing Radiator	Pounds of Steam Condensed per Sq. Ft. of Radiation	B. T. U. per Sq. Ft. per Degree Difference in Temperature of Air and Steam
50	147	.137	.859
75	143	.200	1.23
100	140	.262	1.60
125	138	.324	1.97
150	135	.379	2.29
175	132	.432	2.58
200	130	.484	2.88
225	127	.535	3.14
250	123	.576	3.35
275	121	.623	3.60
300	119	.667	3.83

In school buildings and in buildings where the flues are of ample size the amount of air passing per square foot of radiating surface may be assumed to be 200 cubic feet per hour. In residences and buildings where the flues are usually small, the amount of air passing per square foot of surface per hour does not exceed 150 cubic feet.

NOTE.—Above information is quoted from Notes on Heating and Ventilation by Professor John R. Allen.

B. T. U. Required for Heating Air

This table specifies the quantity of heat in British thermal units required to raise one cubic foot of air through any given temperature interval.

External Temp.	Temperature of Air in Room									
	40°	50°	60°	70°	80°	90°	100°	110°	120°	130°
–40°	1.802	2.027	2.252	2.479	2.703	2.928	3.154	3.379	3.604	3.829
–30°	1.540	1.760	1.980	2.200	2.420	2.640	2.860	3.080	3.300	3.520
–20°	1.290	1.505	1.720	1.935	2.150	2.365	2.580	2.795	3.010	3.225
–10°	1.051	1.262	1.473	1.684	1.892	2.102	2.311	2.522	2.732	2.943
0°	0.822	1.028	1.234	1.439	1.645	1.851	2.056	2.262	2.467	2.673
10°	0.604	0.805	1.007	1.208	1.409	1.611	1.812	2.013	2.215	2.416
20°	0.393	0.590	0.787	0.984	1.181	1.378	1.575	1.771	1.968	2.165
30°	0.192	0.385	0.578	0.770	0.963	1.155	1.345	1.540	1.733	1.925
40°	0.000	0.188	0.376	0.564	0.752	0.940	1.128	1.316	1.504	1.692
50°	0.000	0.000	0.184	0.367	0.551	0.735	0.918	1.102	1.286	1.470
60°	0.000	0.000	0.000	0.179	0.359	0.538	0.718	0.897	1.077	1.256
70°	0.000	0.000	0.000	0.000	0.175	0.350	0.525	0.700	0.875	1.049

Above table from F. Schumann's Manual of Heating and Ventilation, pages 64 and 41.

ABSOLUTE zero of temperature is 491.6 Fahrenheit below the melting point of ice, 32° Fahrenheit. It is only necessary to add (491.6°—32°) to the actual thermometer reading to get the absolute temperature. For engineering work 460° is used rather than 459.6.

Heat

The unit of heat quantity in the English system is known as a British Thermal Unit—B. T. U.—and is the amount of heat required to raise 1 pound of water from 62° to 63° Fahrenheit, while in the French system the unit is called a Calorie and is the amount of heat required to raise 1 kilogram of water from 15° to 16° centigrade (C). Since 1 k. g. = 2.2046 pounds and 1° C=9/5 F, then 1 Cal.=(2.2046 x 9/5=3.968 B. T. U. or 1 B. T. U.=.252 Cal. In engineering work it is sufficiently accurate to consider a B. T. U. as the mean or average amount of heat per degree required to raise 1 pound of water from 32° to 212° F.

The specific heat of any substance can be expressed as the number of B. T. U. required to raise or lower the temperature of 1 pound at a given temperature 1 degree F.

When heat is added to a substance without change of state we increase its temperature and the heat thus added is known as sensible heat. When heat added to a substance causes a change of state from solid to a liquid, without increasing its temperature, the heat thus added is known as latent heat of fusion, and when heat added causes a change of state from liquid to vapor, the heat thus added is known as latent heat of evaporation. In the case of water at atmospheric pressure, evaporation takes place at 212° F. and the latent heat amounts to 970.4 B. T. U. per pound of water.

Heat by conduction is a molecular transmission of heat, the material in question transmitting the heat from particle to particle of its own substance. This transmission will only occur between any two sections of the material which are at different temperatures, the heat always flowing from the higher to the lower temperature.

Heat by convection is the transmission of heat by the circulation of one substance over the surface of a hotter or colder body.

Heat by radiation is the transmission of heat through a medium commonly known as ether, in the same manner that light is transmitted.

To Determine Boiler Capacity Required to Heat Swimming Pool

L x W x D equals cubic feet. Where L equals the length of the pool in feet, W equals the width and D equals the average depth of the water.

From table, page 55-56, determine the number of pounds per cubic foot at initial temperature of the water. This quantity multiplied by the number of cubic feet gives the number of pounds of water to be heated.

Pounds of water multiplied by the difference between initial and final temperature equals B. T. U. to be supplied, and dividing by the number of hours allowed for heating gives number of B. T. U. required to be supplied per hour.

Divide B. T. U. required per hour by 225 (150 + 75) to determine capacity of water boiler under Guaranteed Heating; and 360 (240 + 120) to determine capacity of steam boiler.

Note.—If quantity of water is given in gallons multiply by 8⅓ (approximately 8⅓ pounds to the gallon) to reduce it to pounds.

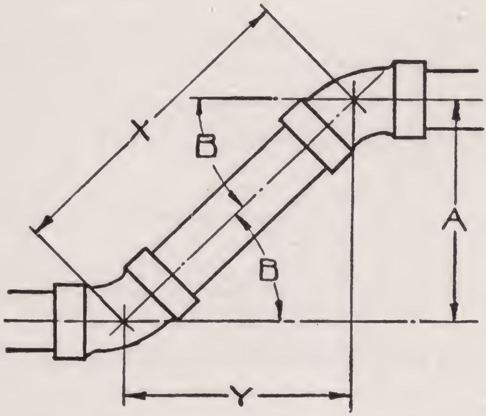
Expansion of Wrought-Iron Pipe on the Application of Heat

Temp. Air When Pipe is Fitted	Increase in Length in Inches per 100 Feet When Heated to							
Deg. F.	160	180	200	212	220	228	240	274
0	1.28	1.44	1.60	1.70	1.76	1.82	1.92	2.19
32	1.02	1.18	1.34	1.44	1.50	1.57	1.66	1.94
50	.88	1.04	1.20	1.30	1.36	1.42	1.52	1.79
70	.72	.88	1.04	1.14	1.20	1.26	1.36	1.63

Table of Mains and Branches

Main	Branch			
1 " will supply 2	....			¾"
1¼" will supply 2	....			1 "
1½" will supply 2	....			1¼"
2 " will supply 2	....			1½"
2½" will supply 2	1½" and 1	1¼" or 1	2 " and 1	1¼"
3 " will supply 1	2½" and 1	2 " or 2	2 " and 1	1½"
3½" will supply 2	2½" or 1	3 " and 1	2 " or 3	2 "
4 " will supply 1	3½" and 1	2½" or 2	3 " or 4	2 "
4½" will supply 1	3½" and 1	3 " or 1	4 " and 1	2½"
5 " will supply 1	4 " and 1	3 " or 1	4½" and 1	2½"
6 " will supply 2	4 " and 1	3 " or 4	3 " or 10	2 "
7 " will supply 1	6 " and 1	4 " or 3	4 " and 1	2 "
8 " will supply 2	6 " and 1	5 " or 5	4 " and 2	2 "

Used in General Practice



X (Center to Center) = A (Offset) Multiplied by Constant.
Y (Center to Center) = A (Offset) Multiplied by Constant.

B—Angle	Constant	
	For X	For Y
60 Degrees	1.15	.58
45 Degrees	1.41	1.00
30 Degrees	2.00	1.73
22½ Degrees	2.61	2.41
11¼ Degrees	5.12	5.02
5⅝ Degrees	10.20	10.15

Square Feet of Radiating Surface for Various Lengths of Pipe Per Lineal Foot

On all lengths over one foot, fractions less than tenths are added to or dropped.

Length of Pipe in ft.	SIZE OF PIPE										
	¾	1	1 ¼	1 ½	2	2 ½	3	3 ½	4	5	6
1	.275	.346	.434	.494	.622	.753	.916	1.047	1.175	1.455	1.739
2	.5	.7	.9	1.0	1.2	1.5	1.8	2.1	2.4	2.9	3.5
3	.8	1.0	1.3	1.5	1.9	2.3	2.7	3.1	3.5	4.4	5.2
4	1.1	1.4	1.7	2.0	2.5	3.0	3.6	4.2	4.7	5.8	7.0
5	1.4	1.7	2.2	2.4	3.1	3.8	4.6	5.2	5.8	7.3	7.7
6	1.6	2.1	2.6	2.9	3.7	4.5	5.5	6.3	7.0	8.7	10.5
7	1.9	2.4	3.0	3.4	4.4	5.3	6.4	7.3	8.2	10.2	12.1
8	2.2	2.8	3.5	3.9	5.0	6.0	7.3	8.4	9.4	11.6	13.9
9	2.5	3.1	3.9	4.4	5.6	6.8	8.2	9.4	10.6	13.1	15.7
10	2.7	3.5	4.3	4.9	6.2	7.5	9.1	10.5	11.8	14.6	17.4
11	3.0	3.8	4.8	5.4	6.8	8.3	10.0	11.5	12.9	16.0	19.1
12	3.3	4.1	5.2	5.9	7.5	9.0	11.0	12.6	14.1	17.4	20.9
13	3.6	4.5	5.6	6.4	8.1	9.8	11.9	13.6	15.3	18.9	22.6
14	3.8	4.8	6.1	6.9	8.7	10.5	12.8	14.7	16.5	20.3	24.3
15	4.1	5.2	6.5	7.4	9.3	11.3	13.7	15.7	17.6	21.8	26.1
16	4.4	5.5	6.9	7.9	10.0	12.0	14.6	16.7	18.8	23.2	27.8
17	4.7	5.9	7.4	8.4	10.6	12.8	15.5	17.8	20.0	24.7	29.5
18	5.0	6.2	7.8	8.9	11.2	13.5	16.5	18.8	21.2	26.2	31.3
19	5.2	6.6	8.3	9.4	11.8	14.3	17.4	19.9	22.3	27.6	33.1
20	5.5	6.9	8.7	9.9	12.5	15.0	18.3	20.9	23.5	29.1	34.8
25	6.9	8.6	10.9	12.3	15.6	18.8	22.9	26.2	29.3	36.3	43.5
30	8.3	10.4	13.0	14.8	18.7	22.5	27.5	31.4	35.3	43.6	52.1
35	9.6	12.1	15.2	17.3	21.8	26.3	32.0	36.6	41.1	50.9	60.8
40	11.0	13.8	17.4	19.8	24.9	30.1	36.6	41.9	47.0	58.2	69.5
45	12.4	15.6	19.5	22.2	28.0	33.8	41.2	47.1	52.9	65.5	78.2
50	13.8	17.3	21.7	24.7	31.1	37.6	45.8	52.3	58.7	72.7	87.0
55	15.2	19.0	23.9	27.1	34.3	41.3	50.4	57.6	64.6	80.1	95.6
60	16.6	20.8	26.0	29.6	37.3	45.2	55.0	62.8	70.5	87.3	104.3
65	18.0	22.6	28.2	32.1	40.5	48.8	59.5	68.0	76.4	94.5	112.9
70	19.4	24.2	30.4	34.6	43.5	52.7	64.1	73.3	82.3	101.9	121.7
75	20.7	26.0	32.6	37.1	46.6	56.5	68.7	78.5	88.1	109.1	130.4
80	22.0	27.7	34.7	39.6	49.8	60.2	73.3	83.8	94.0	116.4	139.1
85	23.4	29.4	36.9	42.0	53.4	63.9	77.8	89.0	99.9	123.7	147.9
90	24.8	31.1	39.1	44.5	56.0	67.8	82.4	94.2	105.8	130.9	156.5
95	26.2	32.9	41.2	46.9	59.6	71.5	87.2	99.5	111.6	138.2	165.2
100	27.5	34.6	43.4	49.4	62.2	75.3	91.6	104.7	117.5	145.5	173.9

The above table will be found very convenient in estimating the amount of radiating surface in mains, etc.

NOTE—Above information is quoted from standard authorities. Not guaranteed.

Number of Threads per Inch of Screw	27	18	18	14	14	11½	11½	11½	11½	8
Number of Perfect Threads	5.13	5.22	5.40	5.46	5.60	5.87	6.21	6.33	6.67	7.12
Total Length of Thread and Length of Taper at Top	.41	.62	.63	.82	.83	1.03	1.06	1.07	1.10	1.64
Length of Perfect Thread	.19	.29	.30	.39	.40	.51	.54	.55	.58	.89
Outside Diameter of Perfect Thread	.405	.540	.675	.840	1.05	1.31	1.66	1.90	2.37	2.87
Depth of Thread	.029	.044	.044	.057	.057	.069	.069	.069	.069	.100
Outside Diameter of Thread at End of Pipe	.393	.522	.656	.816	1.025	1.283	1.627	1.866	2.339	2.818
Root Diameter of Thread at End of Pipe	.334	.433	.568	.702	.911	1.144	1.488	1.728	2.201	2.618
Taper of Thread per Inch of Screw	1/32	1/32	1/32	1/32	1/32	1/32	1/32	1/32	1/32	1/32
Size of Tap Drill	21/64	29/64	19/32	23/32	15/16	1 3/16	1 15/32	1 23/32	2 3/16	2⅝

Length of Pipe in Feet Containing One U. S. Gallon	Length of Pipe in Feet Containing One Cubic Foot	U. S. Gallons Contained in One Lineal Foot of Pipe	Pounds of Water Contained in One Lineal Foot of Pipe	Square Feet of Outside or Radiating Surface per Lineal Foot of Pipe	Length of Pipe in Feet per Square Foot Inside Surface	Length of Pipe in Feet per Square Foot Outside or Radiating Surface	
337.72	2526.	.003	.024	.106	14.200	9.431	⅛
185.096	1383.8	.005	.045	.141	10.494	7.074	¼
100.785	754.36	.009	.082	.177	7.748	5.059	⅜
63.322	473.91	.015	.131	.220	6.141	4.547	½
36.116	270.03	.027	.230	.275	4.636	3.638	¾
22.280	166.62	.044	.374	.344	3.641	2.905	1
12.867	96.275	.077	.647	.434	2.768	2.301	1¼
9.454	70.733	.105	.881	.497	2.372	2.010	1½
5.736	42.913	.174	1.453	.622	1.848	1.608	2
4.020	30.077	.248	2.073	.753	1.547	1.329	2½
2.593	19.479	.384	3.201	.916	1.145	1.091	
1.947	14.565	.513	4.281	1.047	1.077	.955	
1.512	11.312	.661	5.512	1.178	.949	.849	
1.207	9.030	.828	6.905	1.309	.848	.764	
.961	7.197	1.039	8.662	1.456	.757	.687	
.666	4.984	1.500	12.510	1.734	.630	.577	
.496	3.717	2.012	16.774	1.996	.544	.501	
.384	2.878	2.598	21.662	2.258	.479	.443	

.055	.060	.060	.085	.115	.170	.230	.275	.370	.585
.068	.088	.091	.109	.113	.133	.140	.145	.154	.203
.205	.294	.421	.542	.736	.951	1.272	1.494	1.933	2.315
			.244	.422	.587	.884	1.088	1.49	1.755
.19	.29	.30	.39	.40	.51	.54	.55	.58	.89

WROUGHT PIPE DATA

8	8	8	8	8	8	8	8
7.60	8.00	8.40	8.80	9.28	10.08	10.88	11.68
1.70	1.75	1.80	1.85	1.91	2.01	2.11	2.21
.95	1.00	1.05	1.10	1.16	1.26	1.36	1.46
3.50	4.00	4.50	5.00	5.56	6.62	7.62	8.62
.100	.100	.100	.100	.100	.100	.100	.100
3.443	3.938	4.43	4.93	5.48	6.54	7.54	8.53
3.243	3.738	4.233	4.73	5.28	6.34	7.34	8.33
$\frac{1}{32}$	$\frac{1}{32}$	$\frac{1}{32}$	$\frac{1}{32}$	$\frac{1}{32}$	$\frac{1}{32}$	$\frac{1}{32}$	$\frac{1}{32}$
3 $\frac{1}{4}$	3 $\frac{3}{4}$	4 $\frac{1}{4}$	4 $\frac{3}{4}$	5 $\frac{5}{16}$	6 $\frac{5}{16}$	7 $\frac{3}{8}$	8 $\frac{3}{8}$

								Actual Outside Diameter	Actual Inside Diameter	Outside Area	Inside Area	Area of Metal	Outside Circumference	Inside Circumference	Weight per Foot
								.405	.269	.129	.057	.072	1.272	.845	.246
								.540	.364	.229	.104	.125	1.696	1.144	.426
								.675	.493	.358	.191	.167	2.121	1.549	.570
								.840	.622	.554	.304	.250	2.639	1.954	.855
								1.050	.824	.866	.533	.333	3.299	2.589	1.140
								1.315	1.049	1.358	.864	.494	4.131	3.296	1.690
								1.660	1.380	2.164	1.496	.668	5.215	4.335	2.290
								1.900	1.610	2.835	2.036	.799	5.969	5.058	2.740
								2.375	2.067	4.430	3.356	1.074	7.461	6.494	3.690
								2.875	2.469	6.492	4.778	1.704	9.032	7.757	5.850
3								3.500	3.068	9.621	7.393	2.228	10.996	9.638	7.660
	3½							4.000	3.548	12.566	9.887	2.679	12.566	11.146	9.240
		4						4.500	4.026	15.904	12.730	3.174	14.137	12.648	10.900
			4½					5.000	4.506	19.635	15.947	3.668	15.708	14.156	12.700
				5				5.563	5.047	24.306	20.006	4.300	17.477	15.856	14.900
					6			6.625	6.065	34.472	28.890	5.582	20.813	19.054	19.200
						7		7.625	7.023	45.664	38.780	6.926	23.955	22.063	23.800
							8	8.625	7.981	58.426	50.027	8.399	27.096	25.073	28.900

.765	.920	1.09	1.27	1.48	1.92	2.38	2.88	Price of Pipe per Foot
.216	.226	.237	.247	.258	.280	.301	.322	Thickness
2.892	3.358	3.818	4.280	4.813	5.751	6.625	7.625	Actual Inside Diameter Extra Strong
2.284	2.716	3.136	3.564	4.063	4.875	5.875	6.875	Actual Inside Diameter Double Extra Strong
.95	1.00	1.05	1.10	1.10	1.26	1.36	1.46	—Inches—Total Distance Pipe Screws Into Fitting

Proportioning Single Pipe Steam Mains

Square Feet Radiation	TOTAL LENGTH OF MAIN IN FEET						
	20	40	75	100	150	200	Return
	Diam., Inches	Diam., Inches	Diam., Inches	Diam., Inches	Diam., Inches	Diam., Inches	Diam., Inches
100	1½	1½	1½	1½	1½	2	1
200	1½	1½	2	2	2	2	1¼
300	2	2	2	2	2	2½	1¼
400	2	2	2½	2½	2½	2½	1¼
500	2½	2½	2½	3	3	3	1¼
600	2½	3	3	3	3	3½	1½
700	2½	3	3	3	3½	3½	1½
800	3	3	3	3	3½	3½	1½
1000	3	3½	3½	3½	3½	4	2
1200	3½	4	4	4	4	4	2
1400	3½	4	4	4	4	5	2
1600	4	4	4	5	5	5	2½
1800	4	5	5	5	5	5	3
2000	4	5	5	5	5	5	3
2500	5	5	5	5	6	6	3
3000	5	5	6	6	6	6	3
3500	5	6	6	6	6	7	3
4000	6	6	6	7	7	7	3½
5000	7	7	7	8	8	8	4
6500	8	8	8	9	9	9	5

Reduce all radiating surface to equivalent in direct surface.

Heat Transmitted Per Hour Per Sq. Ft. by Wrought Iron Pipes in Still Air

Steam

T	219.4	219.4	219.4	219.4	219.4	219.4	219.4	219.4
T1	40	45	50	55	60	65	70	75
T2	179.4	174.4	169.4	164.4	159.4	154.4	149.4	144.4
H	358.8	348.8	338.8	328.8	318.8	308.8	298.8	288.8
W	.372	.361	.351	.341	.330	.320	.3095	.299
E	1.488	1.444	1.404	1.364	1.320	1.280	1.238	1.196

Water

T	180	180	180	180	180	180	180	180
T1	40	45	50	55	60	65	70	75
T2	140	135	130	125	120	115	110	105
H	252	243	234	225	216	207	198	189
E	1.68	1.62	1.56	1.50	1.44	1.38	1.32	1.26

P—Gauge Pressure 2.3 lbs. for steam or 180° Temp. for water.
T—Temperature of Steam at 2.3 lbs. 219.4° or Temp. of water 180°.
T1—Temperature of surrounding air.
T2—Temperature difference of steam or water and air.
H—B. T. U. transmitted per hour sq. ft. (T2 x 2) for steam. (T2 x 1.8) for water.
L—Latent heat of steam at 2.3 lbs. pressure 965.6 B. T. U.
W—Condensation in lbs. water H ÷ L.
K—Average B. T. U. transmitted per sq. ft. per hour per degree temperature difference. Difference taken as 2 for steam and 1.8 for water. These are conservative factors.
E—Equivalent in direct cast iron.

Risers for Hot Water

Floor	1	2	3	4	5	6
F	1.00	1.41	1.72	1.98	2.24	2.44

"F" is the percentage of increased surface a riser will carry due to head, taking first floor as one.

Mr. N. S. Thompson gives the following equalizing numbers, which represent relative capacities of different pipe sizes for the same friction pressure loss per hundred foot of run in mains and risers serving more than one radiator.

½ inch = 2	1¼ inch = 20	2½ inch = 110	4 inch = 380	7 inch = 1600
¾ inch = 5	1½ inch = 30	3 inch = 175	5 inch = 650	8 inch = 2250
1 inch = 10	2 inch = 60	3½ inch = 260	6 inch = 1050	

Example

one 4 inch = 380
one 5 inch = 650

1030

One 6 inch main would supply one 4 inch and one 5 inch.

Comparisons of Heat Losses Through Different Commercial Insulating Materials

Test Material No.	NAME	Temperature Difference—Deg. Fahr. 100	200	300	400	500	Thickness Ins. Actual	Ins. Apparent	Wt. per Lin. Ft.	Conditions for which recommended by Manufacturer
		B. T. U. per sq. ft. of pipe surface per deg. Temp. dif. per hr.								
I	J-M 85% Magnesia	0.381	0.397	0.413	0.429	0.445	1.11	1.18	2.73	High Pressure Steam
II	J-M Indented	0.483	0.509	0.549	0.603	0.666	.....	1.12	3.46	High Pressure Steam
III	J-M Vitribestos	0.654	0.715	0.781	0.858	0.967	0.96	1.11	4.05	Stack and breeching linings
IV	J-M Eureka	0.451	0.464	0.478	.....	.....	.....	1.04	4.60	L. p. s. and h. w.
V	J-M Molded Asbestos	0.522	0.539	0.561	0.596	.....	1.25	1.26	5.53	L. p. s. and Med. pres. steam
VI	J-M Wool Felt	0.400	0.421	0.442	.....	.....	.....	1.10	2.59	L. p. s. and h. w.
VII	Sall-Mo Expanded	0.427	0.464	0.503	0.541	0.581	.....	1.07	3.47	High Pressure Steam
VIII	Carey Carocel	0.378	0.421	0.466	0.510	0.562	0.99	1.06	3.06	Med. and L. p. s.
IX	Carey Serated	0.468	0.506	0.546	0.587	0.634	1.00	1.13	5.66	High Pressure Steam
X	Carey Duplex	0.447	0.498	0.548	.....	.....	.96	1.01	1.79	L. p. s. and h. w.
XI	Carey 85% Magnesia	0.418	0.424	0.436	0.454	0.472	1.10	1.19	2.74	High Pressure Steam
XII	Sall-Mo Wool Felt	0.410	0.433	0.459	.....	.....	.....	1.01	3.73	L. p. s. and h. w.
XIII	Nonpareil High Pressure	0.402	0.412	0.426	0.444	0.465	1.16	1.23	2.96	H. p. and Superheated Steam
XIV	J-M Asbestos Fire Felt	0.711	0.749	0.795	0.845	0.901	.99	1.09	3.75	H. p. and Superheated Steam
XV	J-M Asbestos-Sponge Felted	0.347	0.369	0.391	0.414	0.439	.....	1.16	4.04	H. p. and Superheated Steam
XVI	J-M Asbestocel	0.429	0.454	0.493	0.544	0.609	.....	1.10	1.94	Med. and L. p. s. and h. w.
XVII	J-M Air Cell	0.475	0.515	0.571	0.643	0.733	1.00	1.11	1.55	L. p. s. and h. w.
XX	Plastic 85% Magnesia	0.470	0.488	0.505	0.522	0.539	1.05	1.05	3.33	Fittings and Irregular Surfaces
XXIV	Sall-Mo Air Cell	0.539	0.603	0.681	0.771	0.871	.....	0.95	1.57	L. p. s. and h. w.*

*Apparent thickness is distance from pipe surface to outer surface of insulation.
NOTE—L. p. s. = low pressure steam; h. w. = hot water.
From "Heat Insulation Facts" by L. B. McMillan, A. S. H. V. E. Journal, May, 1920.

MAGNESIA CEMENT NEEDED TO COVER FITTINGS

In pounds

Pipe Size Inches	Regular Ells			Long Radius Ells and Tees			Std. Flanged Joint		Extra Heavy Flange		Globe Valve		
	1″	2″	3″	1″	2″	3″	1″	2″	2″	3″	1″	2″	3″
1	.4	1.2	2.5	.8	2.0	4.0	2.0	9.7	9.7	20.	1.5	3.0	6.
1¼	.5	1.4	2.8	.9	2.2	4.5	2.1	10.1	10.1	21.	1.7	3.5	6.5
1½	.6	1.7	3.3	1.0	2.7	5.0	2.2	10.6	10.5	22.	2.0	4.0	7.
2	1.0	2.2	4.	1.2	3.2	6.0	2.7	11.5	11.5	23.3	2.8	5.	8.5
2½	1.2	2.8	5.	1.7	4.	7.4	3.2	12.5	12.7	25.	3.2	6.	9.7
3	1.4	3.2	6.	2.0	5.	8.7	3.6	13.5	14.3	27.	4.0	7.2	11.3
3½	1.7	4.	7.	2.5	5.8	10.2	4.	14.3	16.	28.	4.8	8.3	13.0
4	2.0	4.8	8.2	3.0	7.	12.	4.3	15.2	17.5	30.	5.4	9.4	14.5
4½	2.4	5.6	9.6	3.4	8.	13.4	4.7	16.	19.	33.	6.2	10.6	16.5
5	2.8	6.3	11.	4.0	9.	15.2	5.	17.	20.6	35.	7.0	12.	19.
6	3.6	8.	13.3	4.3	12.	19.5	6.	19.	24.	40.	8.2	15.	23.5
7	4.3	9.5	15.8	6.7	14.6	24.5	7.	21.	27.	45.	10.0	17.8	29.
8	5.	11.	18.3	8.1	17.	29.3	7.8	22.7	30.2	50.	11.5	20.8	34.5
9	6.3	14.	22.2	9.7	21.5	35.0	8.6	24.5	33.3	55.	13.0	25.2	41.
10	7.6	16.	26.	11.6	25.5	41.	9.3	26.5	36.6	60.	14.5	30.	48.
12	10.0	21.	33.8	16.0	34.0	55.	11.	30.	43.	70.	18.5	39.	62.

Note—For Standard Cross add 25 per cent to the amount required for a Long Radius Elbow.

For No. 102 Asbestos Cement multiply the above quantity by two, and for No. 3 Asbestos Cement multiply by 2½.

The amount given does not include flanges. The valves used as a basis of computation are standard globe valves and are assumed to be covered to the flange by which the valve is dismounted in order to get at the valve seat.

Flange joints are assumed to be covered in accordance with the following rules:

1. The pipe covering itself is cut back from the flanges sufficient to take out the bolts and this cut-back is made on both sides so that the flange may be bolted up in either direction.

2. This cut-back is beveled out to the outside of the covering at 45°.

3. The flange joint cover is taken to be of rectangular axial section, the inside of the end walls extending to the limit of the pipe covering cut out for the flange bolts. The outside diameter of the flange cover is assumed to clear the flange by ¼ inch.

4. The flange joint cover is of the same thickness as the adjacent pipe covering.

(Taken from the Franklin Manufacturing Co. catalogue by permission.)

To Cover Square Boilers 1½ Inches Thick

Number	Pounds	Number	Pounds	Number	Pounds
184	200	727	400	1040	675
185	225	827	450	1140	750
186	250	927	500	1240	825
187	275	1027	550	1340	900
204	300	1127	600	WN276	750
205	325	1227	650	WN277	850
206	350	235	550	WN278	950
207	375	236	610	WN279	1050
520	325	237	670	WN280	1150
620	350	238	730	WN281	1250
720	375	239	790	WN282	1350
820	400	240	850	WN283	1450
255	425	4106	375	WN284	1550
256	475	4107	450	750	850
257	525	4108	525	850	950
258	575	4109	600	950	1050
G276	350	4110	675	1050	1150
G277	400	4111	750	1150	1250
G278	450	740	450	1250	1350
G279	500	840	525	1350	1450
627	350	940	600		

Amount of Asbestos Cement Required for Covering Capitol Winchester Boilers 1½ Inches Thick

GROUP A		GROUP B		GROUP C	
Boiler No.	Lbs.	Boiler No.	Lbs.	Boiler No.	Lbs.
24	150	25	150	..	...
31	150	32	175	33	175
34	150	35	175	36	175
45	200	46	200	47	225
55	200	56	225	57	225
65	250	66	275	67	300
75	250	76	275	77	300
85	300	86	300	87	325

Sufficient sheep's wool cement or boiler putty for sealing the flues and for making the outside of the boiler smoke and fire tight is furnished with all Capitol Boilers. Asbestos cement for covering the boiler will be furnished at an extra charge, on special order.

Asbestos should be applied as follows: About twenty-four hours before using, mix with water to the consistency of thin mortar, enough asbestos for the first coat, which should be one-half of the entire thickness of the covering, and cover boiler, throwing on by handfuls with just enough force to make it stick without packing too solidly. The more loosely it is applied the more effective. When the first coat is thoroughly dry, apply the second coat in the same manner, having a thicker consistency. The third coat should be applied with a trowel and brought to a smooth finish. It is important for good results to allow each coat to thoroughly dry before applying the next. A canvas or heavy muslin jacket can now be pasted over the asbestos and made moisture-proof by painting with asphaltum. This will insure a permanent covering.

Asbestos is supplied in bags containing 25, 50 and 100 lbs. each.

For Guaranteed Heating

THE performance of steam boilers is based upon a gauge pressure of 2 pounds at the boiler and the condensation of 0.25 pounds of steam per square foot of radiating surface standing in still air of 70 degrees.

The performance of water boilers is based upon water leaving the boiler at 180 degrees temperature and the transmission of 150 B. T. U.'s per square foot of radiating surface standing in still air at 70 degrees.

The above are accepted factors for direct cast iron radiation.

All other forms of radiating surface must be reduced to the equivalent of direct cast iron.

The square feet of surface in mains, branches and returns should be carefully determined and the condensation for steam or cooling effect for water expressed in equivalent of direct cast iron (see table below) and added to direct radiation. For ordinary conditions Guaranteed Heating Capacity includes a correction to allow 25% for surface contained in steam piping and 35% for surface contained in water piping, also provision for peak load. A square foot of surface in steam mains is assumed to condense 0.30 pounds of steam per hour owing to the character of cooling surfaces and relatively low basement temperatures. Piping having greater exposure will have higher condensation. (See table, top page 25.)

A good pipe covering reduces the heat radiated from piping.

The condensation in indirect radiators depends on the temperature and volume of air entering the stack. Prof. Allen gives a value of 0.432 pounds when 175 cubic feet of air per square foot of surface per hour is admitted at zero degrees. (See table, top page 17.)

Indirect radiating surface should be expressed in its equivalent of direct cast iron. (See table below.)

When the pounds steam condensed per square foot per hour of any surface is known its equivalent in direct cast iron surface may be determined by multiplying the amount of surface in square feet by the factor corresponding to that condensing power, given in table below.

Condensing Power, Lbs.	Factor	Condensing Power, Lbs.	Factor	Condensing Power, Lbs.	Factor
.20	.80	.30	1.20	.40	1.60
.21	.84	.31	1.24	.41	1.64
.22	.88	.32	1.28	.42	1.68
.23	.92	.33	1.32	.43	1.72
.24	.96	.34	1.36	.44	1.76
.25	1.00	.35	1.40	.45	1.80
.26	1.04	.36	1.44	.46	1.84
.27	1.08	.37	1.48	.47	1.88
.28	1.12	.38	1.52	.48	1.92
.29	1.16	.39	1.56	.49	1.96

SELECTION OF CAPITOL BOILERS WHEN USED FOR HOT WATER SUPPLY

To determine the size of Capitol Boiler necessary to heat a storage tank: The number of U. S. gallons of water to be heated times 8.33 multiplied by the number of degrees the water is to be heated per hour and divide the product by 300. The result is the equivalent of sq. ft. direct cast iron radiation of Guaranteed Heating.

Example

To raise the temperature 40 degrees of 800 gallons of water per hour: $\frac{800 \times 8.33 \times 40}{300} = 888$ sq. ft. Under Guaranteed Heating in direct cast iron water radiation select nearest size to 888.

Working Pressures

Boilers are built in accordance with the A. S. M. E. Standard, and are tested under water pressure of sixty pounds per square inch. The maximum working pressure should not exceed fifteen pounds per square inch on steam boilers or thirty pounds per square inch on water boilers, unless boiler has been specially tested at the factory at two and a half times the proposed working pressure.

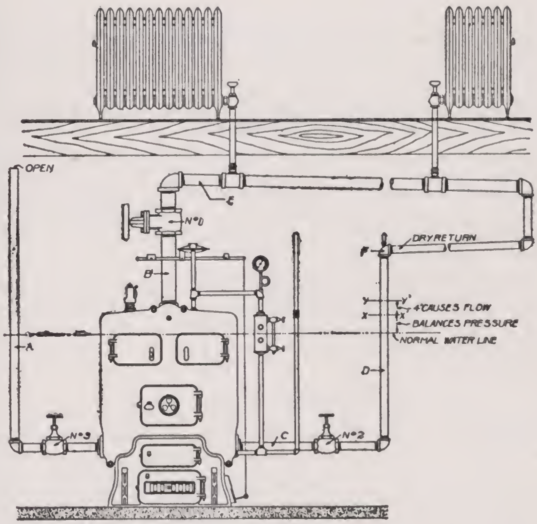
Boilers specially tested for working pressures in excess of fifteen pounds on steam and thirty pounds on water should be equipped with high grade relief valve set to open at a reasonable, predetermined pressure. If requested, affidavit as to test pressure will be supplied but no responsibility against fracture is accepted by this company.

Hot Water Supply Ratings—Water Relief Valves

All water heating boilers and hot water supply boilers should be equipped with water relief valves. The following table gives recommended sizes of relief valves. No valve smaller than ½ inch or larger than 2 inch should be used. Water relief valve should be near boiler with no possibility of stoppage between boiler and valve.

Allowable sizes of water relief valve for Water Heating Boilers and for Water Supply Boilers:

Diam. of Valve Inches	Grate Area Square Feet	Rated Capacity in gallons per hour		
		25° Rise	50° Rise	100° Rise
½	1.60	540	270	135
¾	5.60	1440	720	360
1	9.60	2520	1260	630
1¼	15.75	5400	2700	1350
1½	27.00	10800	5400	2700
2	49.50	21600	10800	5400



ONE of the common causes of water line troubles in steam boilers is insufficient distance between the normal water line of the boiler and the dry return to take care of the inequality in pressure in the heating system.

In the accompanying cut, if the boiler is filled with water to normal water line at center of gauge glass; valves Nos. 1 and 2 are closed, and No. 3 opened, the water will stand in the open pipe "A" at the same height as the water in the boiler.

If a fire is built in the boiler, the steam generated being unable to escape through the pipe "B" will accumulate a pressure which will raise the water in the pipe "A". As the pressure increases the water in the vertical pipe "A" will be raised until the static head of water balances the steam pressure. Every pound of pressure generated will raise the water in the pipe "A" approximately 28″. If the steam pressure were raised high enough the water would be driven out of the top of the vertical pipe.

In an enclosed steam heating plant a similar condition exists, the water in the vertical return pipes balancing the difference in pressure created by the condensation of the steam and pressure loss due to friction.

If the valves 1 and 2 are opened, and No. 3 closed, the water stands in the return pipe "D" at the normal water line level; when steam is formed in the boiler it flows through the vertical pipe "B" and is distributed to the radiators through the horizontal pipe "E". As the steam is condensed its pressure is lost. The frictional loss due to the steam passing through fittings and pipe always causes a drop in pressure, and if the pipe "E" is long, or too small, this loss in pressure becomes a very important consideration and, added to the natural drop in pressure due to the condensing of the steam, results in a material difference in pressure in the system at the points "B" and "F".

As an example, assume that the steam supply main "E" is 125 feet long, and its size has been determined to allow for a pressure drop of 3 ounces. When the steam gauge on the boiler registers two pounds, a steam gauge if placed at "F" would show 29 ounces, and to equalize this difference in pressure the water in pipe "D" would be raised approximately 5¼ inches (1.732 inches per ounce) to a line indicated by X—X′.

Water standing at the height X—X′ represents balanced pressures in the system. However, as steam is condensed, it is necessary to return to the boiler the water accumulating in the pipe "D". To do this the pressure in pipe "D" must exceed the pressure in the boiler, requiring an additional 4 inches of head, making total elevation of 9¼ inches in the return, as indicated by the line Y—Y′.

On account of the high frictional loss often found and increased pressure drop when system is first heating, it is advisable to maintain a distance of at least 18 inches between the normal water line and the point "F", which is the low point of the dry return.

Blowing Off a Steam Boiler

A steam boiler should be blown off within one week after it is in operation, to remove the unavoidable accumulation of oil, grease, etc. which have a tendency to cause foaming, preventing the generation of steam and causing an unsteady water line. This can only be done when the boiler is under fire. If one blowing off does not result in a steady water line and clean gauge, the operation must be repeated a second, or if necessary, a third and fourth time.

Close all radiator valves and remove the thermostatic members of all return line valves, if used, or if boiler is valved, close both the supply and return valves. Remove damper regulator and plug the opening. Remove the 1″ plug in the steam space in front of boiler and connect a blow off pipe to the opening, extending this pipe to a suitable drain or out of the basement window, providing basement window is lower than tapping. The size of this pipe should be the same as the tapping and should be provided with a full sized gate valve.

With sufficient fire in the boiler to keep the water at the boiling point, turn on the cold water supply enough to cause the water in the boiler to overflow slowly through the blow off pipe until the surface of the water line is thoroughly skimmed of all oil and grease. One to two hours is generally sufficient. At intervals the water supply and blow off valves should be closed to allow the temperature of the water to be raised.

The best results in skimming a boiler over the top can be obtained by never permitting the water to boil at such a rate or the water supply valve to be open to such an extent that the overflowing water completely fills the one inch pipe. The flow through this pipe should be slow, so that the grease on top of the water can float away and not be forced against the upper inside surface of the iron in top of boiler.

When you are assured that the overflowing water is free from grease, shut off the water supply valve and gate valve in overflow pipe and draw the water down to its correct water line, then close the lower blow off cock, and using wood as fuel, raise the steam pressure to at least 12 lbs. and open the blow off cock wide, using care to see that the supply of fuel in the boiler is ample to maintain pressure until the last ounce of water has been blown out, but do not have the fuel bed so thick that it will be

difficult to dump the grates when all water has been blown from the boiler and the basement or boiler room has cleared sufficiently of steam to permit you to enter this room.

Open all fire and flue doors wide and allow the boiler to become cool, close the drain cock, remove the surface blow off pipe, replace plug and damper regulator, and fill the boiler slowly to the water line.

Then open all radiator valves, flow and return valves, and if the thermostatic members have been removed from the return line valves, these can be replaced while the boiler is cooling.

Fire can then be rekindled and the boiler tested for steaming.

On large boilers it may be desirable at times to make surface blow off connections at the safety valve tapping, in which case it will be necessary to carry a higher water line to accomplish the skimming action. The rest of the operation will be as already described.

In boilers where a large amount of oil and grease is present it may be desirable to add a quantity of soda ash, which should be boiled in boiler for half an hour before the blowing off operation is started. If soda ash is used it should be purchased from a wholesale drug house or drug store, for package products sold in grocery stores sometimes contain a percentage of soap, which is undesirable for the work to be done.

The quantities of soda ash named below may in some cases be a trifle in excess of that actually required while in others not sufficient, but are fairly good averages of what is generally required to obtain the necessary results.

Guaranteed steam boiler capacity up to 825 sq. ft. . . . . 5 lbs.
Guaranteed steam boiler capacity from 825 to 1350 sq. ft. . . 10 lbs.
Guaranteed steam boiler capacity from 1350 to 2400 sq. ft. . . . 15 lbs.
Guaranteed steam boiler capacity from 2400 to 3500 sq. ft. . . . 20 lbs.
Guaranteed steam boiler capacity from 3500 to 7000 sq. ft. . . . 25 lbs.
Guaranteed steam boiler capacity from 7000 sq. ft. and above . 30 lbs.

When soda ash is used care should be taken to see that all traces of this chemical are removed before the boiler is put into commission. This can be accurately determined by testing the water occasionally with litmus paper during the floating process. Litmus paper can be purchased from any drug store and is sold in two colors; the pink paper should be used for it turns blue when immersed in water containing soda and retains its original color when the water is free from soda. The use of litmus paper is not feasible when natural feed water contains a high percentage of alkali. In such cases the skimming process should be continued from two to three hours, depending on the size of the boiler.

In cases where there is no water supply pressure the surface blow off cannot be a continuous operation. Therefore, the bottom blow off should be repeated several times.

WHEN a gauge glass is removed for cleaning it is sometimes broken and it is frequently necessary to replace the gaskets. By following the instructions given below, the glass may be cleaned without removing it from the boiler. At least a pound pressure should be carried on the boiler during this process.

Draw off a cup of boiling water through the lower gauge cock and add about half an ounce of raw muriatic acid to it.

Close the lower water-gauge valve and open the pet cock at the bottom of the glass and allow the water to be blown out of the glass. Then shut the upper water gauge valve and immediately submerge the pet cock in the hot acid solution. The vacuum created by the cooling of the gauge glass will draw the acid up into the glass.

Keep the pet cock submerged and alternately open and close the upper gauge valve slightly. This will cause the acid to rise and fall in the glass which will cut any oil, grease or rust adhering to the inside of the gauge glass.

After the glass is clean, open both gauge valves and allow water to blow out through the lower pet cock for a few seconds to rinse out any acid, and then close the pet cock.

The cleaning process should not require more than about ten minutes.

Draft Gauge

THE U-Tube Water Gauge is the most commonly used appliance to determine the strength of draft. It is inexpensive, simple in construction and easily operated. Providing the area of flue is ample for proper volume, .12 to .15 inches of water is sufficient for small, and .15 to .2 inches for large installations. The air in flue should be warmed when the gauge is used.

The chimney flue may have area given in table, and, still, because of variations in form or construction, have insufficient intensity, resulting in an excessive consumption of fuel.

Draft Inches of Water	Pressure Pounds per Sq. Ft.	Velocity Feet per Second	Velocity Feet per Minute	Draft Inches of Water	Pressure Pounds per Sq. Ft.	Velocity Feet per Second	Velocity Feet per Minute
.10	.521	15.05	903	1.10	5.731	49.90	2994
.15	.781	18.17	1090	1.15	5.991	51.00	3060
.20	1.042	21.30	1278	1.20	6.252	52.10	3126
.25	1.302	23.05	1327	1.25	6.512	53.20	3189
.30	1.563	26.05	1564	1.30	6.773	54.20	3252
.35	1.823	28.08	1685	1.35	7.033	55.30	3315
.40	2.084	30.10	1806	1.40	7.294	56.30	3378
.45	2.344	31.76	1911	1.45	7.554	57.40	3415
.50	2.605	33.60	2016	1.50	7.815	58.20	3492
.55	2.865	35.20	2112	1.55	8.075	59.30	3523
.60	3.126	36.80	2208	1.60	8.336	60.20	3612
.65	3.386	38.30	2298	1.65	8.596	61.30	3666
.70	3.647	39.80	2388	1.70	8.857	62.00	3720
.75	3.907	41.20	2469	1.75	9.117	63.10	3774
.80	4.168	42.50	2550	1.80	9.378	63.80	3828
.85	4.478	43.80	2628	1.85	9.638	64.90	3882
.90	4.689	45.10	2706	1.90	9.899	65.60	3936
.95	4.949	46.30	2778	1.95	10.159	66.70	3987
1.00	5.210	47.50	2850	2.00	10.420	67.30	4038

Draft is the difference in pressure which causes the flue gases to rise in a chimney. If the gas inside a stack be heated, each cubic foot of it will expand, hence its weight will be less than a cubic foot of colder outside air or gas. Therefore the unit pressure at the base of the chimney, due to the column of heated gas, will be less than that due to a column of cold air or gas of the same height on the outside of the chimney.

A chimney having height H is filled with gas at temperature t_2. If the chimney had sufficient additional height filled with hot gas at temperature t_2, added to the column in the chimney, this heated gas would just balance a column of air of equal cross section at temperature t_1 and height H. In practice this additional column of hot gas is lacking, hence the above system is unbalanced and the flow occurs into the base of chimney in virtue of the difference in head.

This difference in pressure, like the difference in head of water causes a flow of cold air or gas into the base of the chimney. If, just at the point of entrance into the chimney the cold incoming air is warmed up to the chimney temperature, the chimney will always be full of hot gas and the draft action will be continuous.

The difference in pressure or intensity of draft is usually measured in inches of water by means of a U-tube water gauge.

As draft measurements are taken along the path of the gases, the intensity grows less as the points at which the readings are taken are farther from the stack until in the boiler ashpit, with the ashpit doors open for freely admitting the air, there is little or no perceptible rise in the water of the gauge. The breeching, the boiler damper, the boiler flues and the coal on the grates—all retard the passage of the gases and the draft from the chimney is required to overcome the resistance offered by these various factors. The draft in the smoke hood may be 0.2 inches, while in the firebox it may be not over 0.08, the difference being the draft required to overcome the resistance offered in forcing the gases through the boiler.

One of the most important factors to be considered in determining the loss of draft is the pressure required to force the air for combustion through the bed of fuel on the grates. This pressure will vary with the nature of the fuel used.

The theoretical velocity of the flue gases rising in the chimney may be determined from the table, page 34, assuming an average draft intensity of 0.003 inches of water per foot of chimney.

It is found in practice that the above theoretical velocity is never obtained due to friction and other causes. William Kent assumes a layer of gas two inches in thickness as lining the chimney and reducing its effective area by that amount. In this case the calculated velocity should be assumed to be effective over the net area remaining, giving chimney efficiencies varying from 25 to 50 per cent, the lower velocities being obtained on small residence flues and the higher velocities on larger flues.

Intensity of draft determines the velocity of flow through chimney but cross sectional area must be sufficient to pass the necessary volume of gas if the chimney is to have proper capacity. When the amount of air required for combustion is determined and the intensity of draft is known, the required cross sectional area can be calculated. An actual case is given on the next page.

Given data:

10.3 pounds of coal burned per hour.
450° smoke hood temperature.
35 ft. height of chimney.

Calculation:

Assume the actual amount of air required for combustion one hundred per cent more than the theoretical, or 24 pounds of air per pound of coal.

$\frac{10.3 \times 24}{0.0807} = 3{,}063$ cu. ft. per hour at 32°

0.0807 equals weight of gas or air per cubic foot at 32°. Since volume of gas increases in proportion to absolute temperature, the following correction must be made:

$3{,}063 \times \frac{910}{492} = 5{,}665$ cu. ft. of flue gas which chimney must receive at smoke hood temperature.

Where 910=460°+450° and 492=460°+32°. 460 being the number of degrees it is necessary to add to the Fahrenheit temperature scale to give absolute temperatures.

0.003 x 35=0.105 draft in inches of water.

Velocity corresponding to a draft of 0.105 inches of water determined from table page 34 is 15.36 feet per second.

15.36 x 3600 x 0.25=13,825—velocity of gases in feet per hour where 25% is the assumed efficiency of the chimney.

$\frac{5{,}665}{13{,}825} = 0.41$ sq. ft. of cross sectional area.

0.41 x 144=59 sq. in.

It is necessary that the area and height, thickness of walls, general structure, and the position of the outlets with reference to building and other buildings nearby should be carefully noted and observed in selecting or building a flue. Rectangular shapes should never have a difference in width and length more than the ratio of 2:1. No flue should be less than 8 x 8 inside diameter, and not less than 30 feet in height.

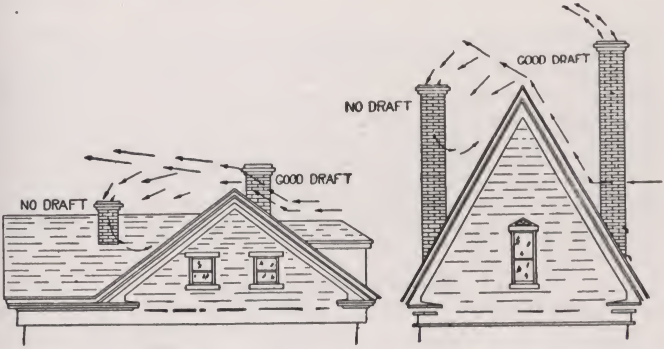
A chimney may have sufficient area and height and still fail to give satisfactory results if certain details of construction are not carefully observed.

The building in which a neater is to be placed should be carefully examined, or if the fitter is figuring from the plans, great care should be taken to ascertain accurately just what kind of a chimney such plans provide. It should be of proper size and of sufficient height to insure a good draft.

Illustrations on tne next page snow the location and height of chimneys on a house tending to make a good and poor draft. A little care and attention to the conditions will save much trouble.

Chimneys which make a turn to go around a fireplace, or which are offset from a vertical position will almost always prove defective unless care is exercised to make the offset very smooth and the area of the chimney larger than if flue be carried "straight up."

The chimney-top should run above the highest part of the roof at least four feet.



The chimney should extend above any surrounding buildings or other obstructions which might cause down air currents.

The chimney should be set on inside wall if possible. If set on outside walls the chimney breast should extend on the inside of the house in preference to extending outside. This is for the reason that the heat radiating from the chimney reduces the intensity of draft.

Short bends for offsets should be avoided.

Enlargement at base or increased cross sectional area of chimney should be avoided.

Chimney caps should not restrict the area. If extension or patent draft accelerators are used, they should have a free area equal to the area of the chimney.

If the flue is tile lined the joints must be well cemented or all space between the tile and brick work filled in tightly.

If the flue is made of brick the outside walls should be at least 8 inches thick to insure safety. The inside joints should be well struck, each course should be well bedded and free from surface mortar at the joints. The exposed brick at the top of chimney should be laid in cement mortar to prevent cutting out of the joints.

Cement Block chimneys having flues of single blocks have in most cases given insufficient draft. The outside walls of flues are only 2 inches to 2½ inches thick and cause chilling of inside air. Then, too, the difference in inside and outside temperature because of block construction causes the thin walls to check or crack a number of times in each block, allowing air leakages. Usually a coarse mixture is used for body of block and only a fine thin mixture for outside facing. This also permits air leakage.

The boiler flue should have no other openings either above or below the boiler smoke pipe, special care being exercised at the base of the flue to prevent any connection between it and the soot pocket of any other flue.

If the chimney contains more than one flue the dividing wall must be carried from the bottom to the top so that each flue is independent of the other throughout its entire length.

When tile linings are used the net inside area should be considered as the size of the chimney flue.

Long smoke pipes should be avoided wherever possible. When they are necessary great care should be taken to see that joints are made tight.

Where the smoke pipe fits the smoke hood and enters the chimney the joints should be made tight with boiler putty or asbestos cement.

In case it is necessary to have a long smoke pipe from the heater to the chimney, great care is necessary to prevent loss of heat. Such a smoke pipe should be one or two inches larger than regular and should have an upward grade to chimney. It should have a good coating of asbestos covering, and there should be as few turns in the pipe as possible.

Smoke pipe should not extend into the flues beyond the inside surface of the lining, otherwise the end of the pipe cuts down the area of the flue.

Round tile linings are rated by inside dimensions. Rectangular linings are rated by outside dimensions.

Fire Clay Flue Linings

Actual Outside Size, Inches	Actual Inside Size, Inches	Actual Inside Area Square Inches	Effective Inside Area Square In.	Weight Pounds Per Foot
	Rectangular			
8½ x 8½	7¼ x 7¼	52.6	41.0	18.5
8½ x 13	7 x 11½	80.5	70.0	28.0
13 x 13	11¼ x 11¼	126.5	99.0	35.5
13 x 18	11¼ x 16¼	182.8	156.0	52.0
18 x 18	15¾ x 15¾	248.0	195.0	69.0
	Round			
7¼	6	28.3	28.3	12.0
9½	8	50.2	50.2	19.5
11¾	10	78.5	78.5	27.7
14	12	113.0	113.0	39.3
17⅛	15	176.7	176.7	54.3
20½	18	254.4	254.4	71.0
22¾	20	314.1	314.1	87.5
27¼	24	452.3	452.3	129.0
34¼	30	706.8	706.8	261.0
41	36	1017.9	1017.9	360.0

Eastern Clay Products Association

Size of Unlined Round Brick Chimneys Equivalent To Unlined and Fire Clay Lined Rectangular Chimneys

Unlined Round Brick Chimney Diameter Inches	Equivalent Chimney		Unlined Round Brick Chimney Diameter Inches	Equivalent Unlined Square Brick Inches
	Unlined Rectangular Brick Inches	Fire Clay Lined Rectangular Inches		
8.0	8 x 8	....	18.4	16 x 20
10.1	8 x 12	....	20.0	20 x 20
11.5	....	8½ x 13	22.4	20 x 24
12.0	12 x 12	....	24.0	24 x 24
14.2	12 x 16	....	26.4	24 x 28
14.8	....	13 x 13	28.0	28 x 28
16.0	16 x 16	....	30.4	28 x 32
17.3	....	13 x 18	32.0	32 x 32
19.8	....	18 x 18	36.0	36 x 36

A table to enable the architectural designer to arrive at the proper size of chimney for his preliminary sketches before the heating requirements have been considered.

By the use of this table, the Architect can determine the chimney size from the area of the window openings; area of exposed wall and cubical contents. These factors represent the heat losses from the building and are constant, regardless of the type of heating system installed.

Diameter of Side of Chimney in Inches, Required for Varying Values of Heat Loss Factor

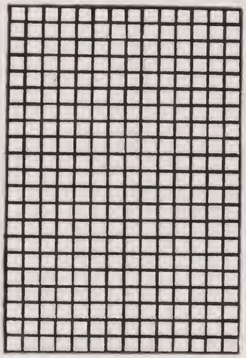
Factor*	HEIGHT OF CHIMNEY IN FEET							
$G+\frac{W}{10}+\frac{C}{100}$	20	30	40	50	60	80	100	120
325	7.4	7.0	....	....	....	....	....	....
675	9.6	9.2	8.8	8.2	....	....	....	....
1000	11.3	10.8	10.2	9.6	9.3	....	....	....
1325	12.8	12.0	11.4	10.8	10.5	10.0	....	....
2000	....	14.4	13.4	12.8	12.4	11.5	11.2	....
2675	....	16.3	15.2	14.5	14.0	13.2	12.6	12.1
4000	....	18.5	18.2	17.2	16.6	15.8	15.0	14.4
5325	....	....	20.8	19.6	19.0	17.8	17.0	16.3
6675	....	....	23.0	21.6	21.0	19.4	18.6	18.0
8000	....	....	25.0	23.4	22.8	21.2	20.2	19.5
9325	....	....	27.0	25.5	24.4	23.0	21.6	20.8
10675	....	....	....	26.8	26.0	24.2	23.4	22.2
12000	....	....	....	28.4	27.4	25.6	24.4	23.4
13325	....	....	....	30.0	28.6	27.0	25.4	24.6
20000	....	....	....	....	35.0	33.0	31.0	29.2
26675	....	....	....	....	41.0	37.0	35.0	34.0
40000	....	....	....	....	48.0	46.0	43.0	41.0

*G—Glass area—sq. ft. W—Wall area—sq. ft. C—Cubic contents—cu. ft.

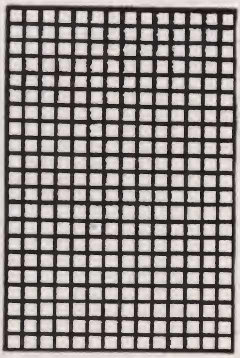
Sizes under heavy black line not recommended.

The most common method for the relative determination of smoke is the Ringelmann Smoke Chart. This chart is published by the U. S. Geological Survey and is shown in reduced size below. The observer places the chart on the level of the eye at such a distance that the lines are obliterated and notes which card most nearly corresponds with the color of the smoke. No smoke is recorded as No. 0, 100 per cent black as No. 5.

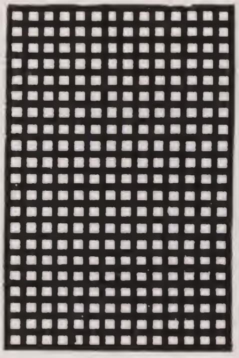
The smokeless performance of a chimney is measured in "smoke units." Various smoke laws differ as to the number of units which may be permitted. A "smoke unit" is the equivalent of No. 1 smoke emitted for one minute.



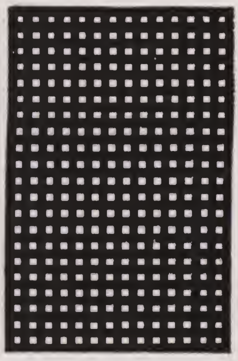
1. 20 Per Cent Black



2. 40 Per Cent Black



3. 60 Per Cent Black



4. 80 Per Cent Black

RINGELMANN SMOKE CHART

CHIMNEY SIZES FOR BOILERS IN BATTERIES

Boiler No.	TWO BOILERS			Boiler No.	TWO BOILERS		
	Square In.	Round Diam.	Height Ft.		Square In.	Round Diam.	Height Ft.
184	12x12	12	35	204	12x12	13	40
185	12x12	12	40	205	12x12	13	40
186	12x12	13	40	206	12x16	15	40
187	12x16	15	40	207	16x16	18	40

Boiler No.	TWO BOILERS			THREE BOILERS			FOUR BOILERS		
	Square Inches	Diam. Inches	Height Feet	Square Inches	Diam. Inches	Height Feet	Square Inches	Diam. Inches	Height Feet
255	12x16	15	40	16x16	18	40			
256	16x16	18	40	16x16	18	45			
257	16x16	18	40	16x20	20	45			
258	16x16	18	45	16x20	20	50			
G276	12x16	15	40	16x20	20	40			
G277	16x16	18	40	16x20	20	45			
G278	16x16	18	45	16x20	20	45			
G279	16x16	18	45	20x20	22	45			

Boiler No.	TWO BOILERS			THREE BOILERS			FOUR BOILERS		
	Square Inches	Diam. Inches	Height Feet	Square Inches	Diam. Inches	Height Feet	Square Inches	Diam. Inches	Height Feet
235	16x16	16	45	20x20	20	45	20x20	20	50
236	16x20	20	45	20x20	20	50	20x24	22	50
237	20x20	20	50	20x20	20	55	24x24	24	50
238	20x20	20	55	20x24	22	55	24x24	24	60
239	20x20	20	60	24x24	24	60	24x28	27	60
240	20x24	22	65	24x24	24	65	24x28	27	65

Boiler No.	TWO BOILERS			THREE BOILERS			FOUR BOILERS		
	Square Inches	Diam. Inches	Height Feet	Square Inches	Diam. Inches	Height Feet	Square Inches	Diam. Inches	Height Feet
4106	20x20	22	50	24x24	27	50	24x28	30	60
4107	24x24	27	50	24x24	27	60	24x28	30	65
4108	24x24	27	60	28x28	28	60	24x28	30	70
4109	24x24	27	65	28x28	30	65	28x32	33	75
4110	24x28	28	70	32x32	32	70	30x36	36	80
4111	28x32	33	75	32x32	33	80	36x36	36	85

Boiler No.	TWO BOILERS			THREE BOILERS			FOUR BOILERS		
	Square Inches	Diam. Inches	Height Feet	Square Inches	Diam. Inches	Height Feet	Square Inches	Diam. Inches	Height Feet
WN276	24x24	26	55	24x28	28	60	24x28	28	65
WN277	24x28	28	60	28x28	32	65	28x28	32	70
WN278	24x28	28	65	28x28	30	70	28x32	33	75
WN279	28x28	32	70	28x32	33	75	32x32	34	80
WN280	28x28	32	75	32x32	34	80	32x36	36	80
WN281	28x32	33	80	32x36	36	80	36x36	40	85
WN282	32x32	36	80	36x36	40	85	40x40	44	85
WN283	36x36	40	80	40x40	44	85	40x40	44	90
WN284	40x40	40	85	44x44	48	85	44x44	48	90

Smokeless Type

Chimney Sizes for Boilers in Batteries
Smokeless Type

Boiler No.	TWO BOILERS			THREE BOILERS			FOUR BOILERS		
	Square Inches	Diam. Inches	Height Feet	Square Inches	Diam. Inches	Height Feet	Square Inches	Diam. Inches	Height Feet
520	12x12	12	45						
620	12x16	15	45						
720	16x16	16	45						
820	16x16	16	50						
627	16x16	18	40	16x20	20	45			
727	16x16	18	40	16x20	20	45			
827	16x16	18	45	20x20	22	45			
927	18x18	20	50	20x20	22	50			
1027	18x18	20	50	20x24	24	50			
1127	18x20	21	50	20x24	24	50			
1227	18x20	21	50	20x24	24	50			
740	24x24	27	50	24x24	27	60	24x28	30	65
840	24x24	27	60	28x28	30	60	24x28	30	70
940	24x24	27	65	28x28	30	65	28x32	33	75
1040	24x28	27	70	32x32	33	70	30x36	36	80
1140	28x28	30	75	32x32	33	80	36x36	40	80
1240	28x32	33	75	30x36	36	80	36x36	40	85
1340	28x32	33	80	30x36	36	85	36x36	40	90
750	24x28	27	65	28x32	33	70	32x32	33	80
850	28x28	28	70	32x32	33	70	30x36	36	80
950	28x32	32	70	32x32	33	80	36x36	40	80
1050	30x36	36	75	36x36	36	80	36x42	42	90
1150	36x36	40	85	40x40	44	85	42x42	48	90
1250	36x36	40	95	42x48	48	95	48x48	48	95
1350	40x40	48	95	42x48	48	100	54x54	54	100

(a) If air is passed upward through a deep bed of ignited carbon devoid of volatile matter, there is a tendency for any CO_2 that is formed in lower layers to be reduced to CO when coming into contact with the carbon above. If this CO is not subsequently supplied with a proper amount of air while still at a high temperature, it will pass off unoxidized and this will result in a loss of heat which would otherwise be made available. It is, therefore, important that an adequate air supply and a suitable temperature be maintained in the upper part of, and just above, the bed of fuel. This air may either pass through the bed or be supplied from above.

The foregoing applies, of course, to the combustion of coke and charcoal as well as to carbon. Anthracite coal, which is mostly fixed carbon, behaves similarly, but in this case there is also a small amount of volatile matter which must be properly burned. These fuels, which have little or no volatile matter, give short flames above the fuel bed, the flames being due to the combustion of CO and the small quantity of volatile matter present.

(b) When coal possessing a considerable amount of volatile matter is placed on a hot bed of fuel, the greater part of the volatile portion distills off as the temperature rises, and the residue, which is coke, burns in the manner just described. The more serious problem that confronts the engineer in this case is the complete oxidation of the combustible part of this volatile matter. Evidently in the ordinary up-draft furnaces that are fired from above the combustion of this part of the fuel must occur above the fuel bed, just as is the case with CO; and in order that the combustible gases may be completely burned, the following four conditions must exist: (1) There must be sufficient air just above the fuel bed, supplied either from above or through the fuel bed itself; (2) this air must be properly distributed and intimately mixed with the combustible gases; (3) the mixture must have a temperature sufficiently high to cause ignition (some of the combustible gases, when mixed with the burned gases present above the fuel, have an ignition temperature of approximately 1450°F); and (4) there must be sufficient time for the completion of combustion, that is, the combustion must be complete before the gases become cooled by contact with the relatively cold walls of the boiler (which are at a temperature of about 220°) or with other cooling surface.

(c) To prevent the stratification of the air and gases, special means are sometimes adopted, such as employing steam jets above the fire and using baffle walls, arches, and piers in the passage of the flame, to bring about an intimate mixture.

(d) In order that the air used above the fuel bed shall not chill and extinguish the flame, it should be heated either by passing it through the fuel bed, or through passages in the hotter parts of the furnace setting, or in some other way before mingling with the gases; or else the mixture of gases and air should be made to pass over or through hot portions of the fuel bed, or should be brought into contact with furnace walls, or

other brickwork, which is at a temperature sufficiently high to support the combustion.

(e) In order that the flame shall not be chilled and extinguished by coming in contact with cold objects, it should be protected by the hot furnace walls until combustion is complete. The furnace should have proper volume to accommodate the burning gases, and, when the conditions are such that the flame is long, the distance from the fuel bed to the relatively cold boiler surfaces with which the gases first come in contact, would be at least as great as the length that the flame attains when the fire is being forced. The length of flame depends on the amount and character of the volatile matter in the fuel, on the rapidity of combustion and on strength of draft. It varies from a few inches, with coke and anthracite coal, to 8 feet or even more with highly volatile coals—even 20 feet has been reached with some western coals.

(f) In order to have complete combustion of all the fuel in a furnace, *it is necessary that uniform conditions prevail throughout the fuel bed;* and to bring this about, it is essential that the fuel itself be uniform in character. Therefore, the best results are obtained with coal that has been graded as to size. Especially is this true with anthracite coal which ignites slowly and is more difficult to keep burning than volatile coals. This coal requires a rather strong draft, and unless the bed is uniform, the rush of air through the less dense portions tends to deaden the fire in those regions, hence good results can be obtained with this coal only when it is uniform in size and evenly distributed. The more common sizes of coal are given in the tables on pages 48 and 49.

(g) Smoke may be composed of unconsumed, condensible tarry vapors, of unburned carbon freed by the splitting of hydro-carbons, of fine non-combustible matter (dust), or of a combination of these. It is an indication of incomplete combustion, and hence of waste, and in certain communities is prohibited by ordinance as a public nuisance. Smoke can be avoided by using a smokeless fuel, such as coke or anthracite coal; or, when the more volatile coals are used, by bringing about complete combustion of the volatile matter. In general, the greater the proportion of the volatile content of the coal, the more difficult it is to avoid smoke, though much depends on the character of the volatile matter. Coals which smoke badly may give from 3 to 5 per cent lower efficiencies than smokeless varieties.

For each kind of coal and each furnace there is usually a range in the rate of combustion within which it is comparatively easy to avoid smoke. At higher rates, owing to the lack of furnace capacity, it becomes increasingly difficult to supply the air, mix it and bring about complete combustion. Hence where there is both a high volatile content in the coal and a rapid rate of combustion, it is doubly difficult to obtain complete and smokeless combustion.

However, although smoke is an indication of incomplete and hence inefficient combustion, it may sometimes be more profitable, because of

lower price or for other reason, to use a coal with which it is difficult to avoid smoke, provided the latter is not a nuisance or is not prohibited by statute. (Above taken from "Elements of Heat Power Engineering," by Hirshfeld and Barnard.)

Cleaning Chimney Flues

A common and efficient method of cleaning a chimney is to sweep it with a properly weighted bundle of rags or a brush attached to a rope and worked from the top.

Other methods of cleaning chimneys recommended as simple and efficient are as follows:

1. The U. S. Fuel Administration strongly advocated the use of salt. The fire should be put in good condition with a substantial body of hot fuel. Well dried common salt is then scattered over the incandescent fuel in quantity depending upon size of furnace. For a household furnace a pound at a time is ample. The dampers should be kept open to maintain the furnace temperature until the fumes entirely disappear. This usually takes about half an hour. The soot is disintegrated by the action of the salt fumes. Repeat the application if necessary.

2. Scrap zinc thrown on a hot fire is said to remove soot by disintegration.

THE general characteristics of the various kinds of coal are given below, in the order of their decreasing fixed carbon content.

Anthracite or hard coal ignites slowly, but when in a state of incandescence its radiant heat is very great. Its flame is very short and of a yellowish blue tinge and it can be burned with practically no smoke. This coal does not swell when burned although it contains from 3 to 7.5% of volatile matter.

True or dry anthracite is characterized by few joints and clefts and their squareness; great relative hardness and density; high specific gravity, ranging from 1.4 to 1.8; and semi-metallic luster.

The anthracite coals are, with some unimportant exceptions, confined to five small fields in Eastern Pennsylvania.

Semi-Anthracite coal kindles more readily, due to its higher content of volatile combustible, and burns more rapidly than anthracite. It has less density, hardness and metallic luster than anthracite and the average specific gravity is about 1.4.

This coal is found in the western part of the anthracite field in a few small areas.

Semi-Bituminous coal is softer than anthracite or semi-anthracite, contains more volatile hydrocarbon and will kindle more easily and burns more rapidly. It is usually free burning and due to its high calorific value very desirable for steam generation purposes.

This coal is found in Pennsylvania, Maryland, Virginia, West Virginia and Tennessee.

Bituminous coals are still softer than those described and contain still more of the volatile hydrocarbons. The difference between the semi-bituminous and the bituminous coals is an important one economically. The former have an average heating value per pound of combustible about 6 per cent higher than the latter, and they burn with much less smoke in ordinary boilers. The distinctive characteristic of the bituminous coals is the emission of yellow flame and smoke when burning. In color they range from pitch black to dark brown, having a resinous luster in the most compact specimens, and a silky luster in such specimens as show traces of vegetable fibre. The specific gravity is ordinarily about 1.3.

Bituminous coals are either of the caking or non-caking class. The former when heated, fuse and swell in size; the latter burn freely, do not fuse and are commonly known as free burning coals. Caking coals are rich in volatile hydrocarbons and are valuable in gas manufacture.

Bituminous coals absorb moisture from the atmosphere. The surface moisture can be removed by ordinary drying, but a portion of the water can be removed only by heating the coal to a temperature of about 250 degrees Fahrenheit.

Bituminous coals have been considered as a single class, but vary greatly in heating value and in the amount of moisture remaining in air-dried coal, which is used as the basis by William Kent of subdividing into three classes:

Bituminous High Grade Coals are found particularly in the Appalachian field in the states of Pennsylvania, West Virginia, Maryland, Virginia, Kentucky, Tennessee, Ohio and Alabama, a field nearly 900 miles in length. The coal mined in this field is mostly caking and is used extensively for steam purposes in the East.

Bituminous Medium Grade Coals are similar to the High Grade Coals but are mostly non-caking. They are found in the middle interior states such as Michigan, Illinois, Indiana, Iowa and Kansas.

Bituminous Low Grade Coal is found particularly in the western states, in the Rocky Mountain region, such as Montana, New Mexico and Utah.

Cannel Coal is a variety of bituminous coal, rich in hydrogen and hydrocarbons, and is exceedingly valuable as a gas coal. It has a dull resinous luster and burns with a bright flame without fusing. Cannel coal is seldom used for steam coal, though it is sometimes mixed with semi-bituminous coal, where an increased economy at high rates of combustion is desired.

Sub-Bituminous Coal sometimes called "black lignite" is organic matter in the earlier stages of its conversion into coal. Its specific gravity is low and when freshly mined it contains a higher percentage of moisture. Its appearance is black with a pitchy luster resembling hard coal in the best varieties. It is non-caking and burns with a bright but slightly smoky flame with moderate heat. Its composition varies over wide limits. The ash may run as low as 1% and as high as 50%. Its high content of moisture and the large quantity of air necessary for its combustion cause large stack losses. It is distinctly a low-grade fuel and is used almost entirely in the districts where mined. It is found in the Western Mountain States such as Montana, Wyoming and Utah.

Lignite is very similar to sub-bituminous coal and is distinguished from it not by analysis but by color, texture and disintegration. Its appearance is brown and has a distinctly woody structure. This fuel contains a high percentage of moisture and if exposed to the weather it rapidly disintegrates, which increases the difficulty of burning. It burns with a short, non-smoky flame similar to wood. Like the sub-bituminous coal, it is a very low grade of fuel and is used only in a few localities where mined. Lignites resemble the brown coals of Europe and are found in the western states, particularly in Texas and North Dakota.

Peat is decayed organic matter which is the first stage in the formation of coal. It is usually found in bogs. When taken from the bogs it contains as high as 75% or more of moisture. The air dried peat will often retain as much as 30% of moisture. There is a considerable supply of peat in this country, but it is very little used as fuel.

Coke is the porous residue left by the destructive distillation of bituminous coal at high temperatures and consists almost entirely of fixed carbon and ash. The name is also applied to the residue from the distillation of coal-tar pitch and asphalt base petroleums. This latter product is of small importance for steam generating purposes.

Anthracite coal is ordinarily marketed under the names and sizes given in the following table:

TRADE NAME	Round Mesh		Testing Segments Standard Square Mesh	
	Through Inches	Over Inches	Through Inches	Over Inches
Broken	4½	3¼	4	2¾
Egg	3¼	2⅜	2¾	2
Stove	2⅜	1⅝	2	1⅜
Chestnut	1⅝	⅞	1⅜	¾
Pea	⅞	⅝	¾	½
No. 1 Buckwheat	⅝	⅜	½	¼
No. 2 Buckwheat or Rice	⅜	$\frac{3}{16}$	¼	⅛
No. 3 Buckwheat or Barley	$\frac{3}{16}$	$\frac{3}{32}$	⅛	$\frac{1}{16}$

Bituminous Coals. There is no classification of bituminous coal as to size that holds good in all localities. The American Society of Mechanical Engineers suggests the following grading:

Eastern Bituminous Coals

(A) Run of mine coal; the unscreened coal taken from the mine.

(B) Lump coal; that which passes over a bar-screen with openings 1¼ inches wide.

(C) Nut coal; that which passes through a bar-screen with 1¼ inch openings and over one with ¾-inch openings.

(D) Slack coal; that which passes through a bar-screen with ¾-inch openings.

Western Bituminous Coals

(A) Run of mine coal; the unscreened coal taken from the mine.

(B) Lump coal; divided into 6-inch, 3-inch and 1¼-inch lump, according to the diameter of the circular openings over which the respective grades pass; also 6 x 3-inch lump and 3 x 1¼-inch lump, according as the coal passes through a circular opening having the diameter of the larger figure and over that of the smaller diameter.

(C) Nut coal; divided into 3-inch steam nut, which passes through an opening 3 inches diameter and over 1¼ inches; 1¼-inch nut, which passes through a 1¼-inch diameter opening and over a ¾-inch diameter opening; ¾-inch nut, which passes through a ¾-inch diameter opening and over a ⅝-inch diameter opening.

(D) Screenings; that which pass through a 1¼-inch diameter opening.

Coke is generally marketed under the following sizes for heating purposes.

TRADE NAMES	Standard Square Mesh Screen Size of Opening in Inches	
	Passes through	Passes over
Egg	3	2½
Large Stove	2½	2
Small Stove	2	1½
Nut	1½	¾
Pea	¾	½

Approximate Weight of Coal Per Cubic Foot

Stove size Anthracite	53 lbs.
Lump Bituminous Coal	48 lbs.
Stove Size Coke	33 lbs

The following table gives the analyses of coal taken from the various coal fields of the United States. This table is compiled from data given in Bureau of Mines Bulletin No. 230, which is a report containing the analyses of all coal delivered to the United States Government during the years 1915 to 1921 inclusive. All analyses tabulated below are averages of the analyses of from 10 to 200 separate samples of coal from the source indicated.

STATE, COUNTY AND TOWN	Proximate Analysis, Per Cent					Calorific Value	
	As received	Dry				B. T. U. Per Pound	
	Moisture	Volatile Matter	Fixed Carbon	Ash	Sulphur	As Received	Dry
ALABAMA							
Bibb, Belle Ellen	1.80	35.83	58.51	5.66	1.39	14,212	14,472
Jefferson, Pinson	3.19	31.38	63.81	4.81	.64	14,186	14,653
St. Clair, Acmar	3.54	35.82	57.02	7.16	.86	13,461	13,955
Walker, Payne Bend	3.39	32.93	55.06	12.01	1.63	12,844	13,295
ARKANSAS							
Sebastian, Greenwood	1.36	18.02	70.39	11.59	3.08	13,459	13,645
COLORADO							
Huerfano, Walsenburg	5.60	38.53	47.23	14.24	.58	11,287	11,957
Las Animas, Brodhead	2.22	38.63	53.55	7.82	.54	13,419	13,724
ILLINOIS							
Clinton, New Baden	10.64	40.40	44.60	15.00	4.37	10,710	11,985
Franklin, Logan	6.23	38.11	49.50	12.39	2.77	11,852	12,639
Madison, Maryville	9.75	40.98	45.32	13.70	4.69	11,066	12,262
Marion, Glenridge	9.05	37.61	51.33	11.06	2.16	11,652	12,811
Perry, Duquoin	8.67	37.07	52.53	10.40	1.65	11,672	12,780
Perry, Winkle	8.92	41.03	45.16	13.81	4.40	11,160	12,253
Saline, Eldorado	7.69	34.80	53.18	12.02	2.32	11,811	12,795
Sangamon, Springfield	12.65	40.22	46.76	13.02	3.82	10,809	12,374
Tazewell, Hilliards	5.63	39.58	48.23	12.19	3.51	11,794	12,498
Vermillion, Danville	12.25	39.70	45.57	14.73	1.47	10,790	12,296
Williamson, Herrin	6.71	34.85	51.79	13.36	2.24	11,741	12,585
INDIANA							
Knox, Bicknell	9.92	40.49	48.86	10.65	3.57	11,572	12,846
IOWA							
Dallas & Boone, Zook Spur	14.10	41.41	41.68	16.91	4.38	10,260	11,944
KANSAS							
Crawford, Frontenac	5.51	35.71	54.03	10.26	4.32	12,606	13,341
Leavenworth, Leavenworth	9.19	39.82	43.98	16.20	4.85	10,981	12,092
Leavenworth, Richardson	8.92	39.40	43.86	16.74	5.23	11,011	12,089
KENTUCKY							
Bell, Amru	2.87	36.25	54.69	9.06	1.36	13,259	13,651
Harlan, Twila	4.47	35.35	55.76	8.89	.85	12,993	13,601
Muhlenberg, Mercer	7.42	39.09	49.84	11.07	3.82	11,941	12,898
Union, Dekoven	5.89	36.41	50.19	13.40	3.61	11,896	12,640

STATE, COUNTY AND TOWN	Proximate Analysis, Per Cent					Calorific Value	
	As Received	Dry				B. T. U. Per Pound	
	Moisture	Volatile Matter	Fixed Carbon	Ash	Sulphur	As Received	Dry
MARYLAND							
Allegany, Frostburg	1.56	18.95	72.74	8.31	.98	14,087	14,310
Allegany, Lonaconing	2.41	19.64	71.51	8.85	1.43	13,878	14,221
Garrett, Dodson	2.86	15.91	71.60	12.49	1.36	13,196	13,585
MONTANA							
Musselshell, Woodard	18.30	39.03	54.37	6.60	.73	10,155	12,430
NEW MEXICO							
Colfax, Dawson	1.79	36.32	47.31	16.37	.69	12,309	12,533
McKinley, Gallup	8.97	40.75	50.13	9.12	.61	11,721	12,876
Rio Arriba, Monero	2.27	39.52	49.06	11.42	3.46	12,752	13,048
Santa Fe, Madrid	2.51	35.03	49.46	15.51	.96	12,215	12,529
NORTH DAKOTA							
Williams, Williston	40.18	49.23	40.30	10.47	1.18	6,582	11,003
OHIO							
Hocking, Coalgate	7.40	39.12	51.91	8.97	1.78	12,044	13,006
Jefferson, Rush Run	4.33	38.04	50.48	11.48	3.52	12,426	12,988
OKLAHOMA							
Okmulgee, Henryetta	4.76	35.94	53.60	10.46	1.77	12,395	13,014
Tulsa, Broken Arrow	5.66	37.86	53.08	9.06	2.78	12,405	13,149
PENNSYLVANIA							
Allegheny, Fair Haven	2.24	35.51	52.70	11.79	1.98	12,866	13,161
Allegheny, Pittsburgh	5.90	32.56	55.43	12.01	1.40	12,153	12,915
Bedford, Six Mile Run	.83	16.00	72.92	11.08	1.69	13,719	13,834
Cambria, Beaverdale	2.77	19.17	72.06	8.77	2.08	13,850	14,245
Cambria, Colver	1.85	23.00	70.13	6.87	1.56	14,298	14,567
Cambria, Elmora	2.71	23.33	68.73	7.94	1.66	14,001	14,391
Cambria, Nanty Glo	2.61	21.89	70.72	7.39	2.43	14,098	14,476
Cambria, Portage	4.24	17.29	73.72	8.99	.97	13,586	14,188
Cambria, Twin Rocks	1.56	22.33	70.79	6.88	1.94	14,334	14,561
Clearfield, Hawk Run	3.44	22.06	67.44	10.50	2.33	13,402	13,879
Indiana, Clymer	3.12	27.80	63.23	8.97	2.11	13,724	14,166
Somerset, Hollsopple	2.06	17.21	73.99	8.80	1.91	13,975	14,269
Somerset, Jerome	2.44	16.99	74.42	8.59	.85	13,947	14,296
Washington, Meadowlands	2.61	40.56	52.25	7.19	2.75	13,337	13,736
Westmoreland, Wyano	6.36	34.62	54.73	10.65	1.54	12,490	13,338
TENNESSEE							
Campbell, Caryville	2.20	35.84	57.32	6.84	.90	13,795	14,105
Grundy, Palmer	5.22	28.60	58.77	12.63	1.03	12,535	13,225
Marion, Whitwell	2.15	29.44	61.62	8.94	.66	13,521	13,818

STATE, COUNTY AND TOWN	Proximate Analysis, Per Cent					Calorific Value	
	As Received	Dry				B. T. U. Per Pound	
	Moisture	Volatile Matter	Fixed Carbon	Ash	Sulphur	As Received	Dry
TEXAS							
Maverick, Eagle Pass....	6.26	30.97	35.71	33.32	.77	8,624	9,200
Webb, Santa Tomas.....	3.93	44.63	37.50	17.87	1.68	11,437	11,905
UTAH							
Carbon, Kenilworth.....	4.51	42.99	50.71	6.30	.54	12,791	13,395
Carbon, Rains..........	3.67	44.41	49.17	6.42	.48	13,012	13,508
Emery, Mohrland.......	5.19	44.10	48.77	7.13	.70	12,658	13,351
VIRGINIA							
Wise, Appalachia........	1.77	35.36	59.46	5.18	.71	14,236	14,493
WASHINGTON							
King, Durham..........	4.63	32.43	50.62	16.95	.81	11,774	12,314
Kittitas, Roslyn.........	4.06	38.23	48.24	13.53	.40	12,309	12,830
Pierce, Carbonado.......	5.78	37.61	50.58	11.81	.60	12,312	13,067
WEST VIRGINIA							
Fayette, Cannelton......	2.31	35.43	57.64	6.93	1.13	13,879	14,207
Fayette, Carbondale.....	1.80	37.04	57.59	5.37	.95	14,260	14,521
Fayette, Newlyn.........	3.11	22.05	74.42	3.53	.66	14,700	15,172
Fayette, Red Star.......	2.77	22.94	71.97	5.09	.71	14,442	14,853
Fayette, Smithers.......	3.56	33.68	57.46	8.86	1.32	13,367	13,860
Kanawha, Standard.....	3.50	33.16	57.84	9.00	.89	13,367	13,852
Logan, Omar...........	10.11	32.72	56.65	10.63	1.26	11,853	13,186
Logan, Yolyn...........	2.17	34.67	57.85	7.48	.78	13,758	14,063
McDowell, Davy........	1.57	18.61	75.13	6.26	.63	14,495	14,726
McDowell, Leckie.......	2.93	19.60	73.96	6.44	.65	14,249	14,679
Marion, Fairmont.......	1.82	38.28	56.00	5.72	.76	14,044	14,304
Mineral, Elk Garden.....	4.08	19.30	70.15	10.55	1.03	13,110	13,668
Mingo, Glen Alum.......	2.33	35.93	58.09	5.98	.78	13,984	14,318
Raleigh, Glen White.....	2.98	18.20	75.45	6.35	.63	14,217	14,654
Raleigh, McVey.........	5.32	17.48	70.68	11.84	1.26	13,000	13,730
Raleigh, Tamroy........	2.94	21.63	72.41	5.96	.72	14,311	14,744
Raleigh, Tams..........	2.87	17.46	76.02	6.52	.63	14,231	14,651
Summers, Claypool......	3.22	18.10	74.77	7.13	.63	14,109	14,578
Summers, Thomas.......	3.63	24.48	66.66	8.86	1.01	13,659	14,173
WYOMING							
Fremont, Hudson.......	20.05	40.06	48.12	11.82	.80	9,152	11,447
Sheridan, Acme.........	22.60	42.93	49.34	7.73	.92	9,315	12,035
Sheridan, Kooi..........	24.18	45.02	43.65	11.33	.86	8,730	11,514
Sweetwater, Superior....	11.57	42.12	50.28	7.60	1.32	11,307	12,786

PETROLEUM is the source of practically all liquid fuels in use today. In its crude state it is a mixture of hydrocarbons which may be separated by fractional distillation.

The petroleums of the United States are of two kinds. The oils obtained in the Appalachian region and the Middle West are of the saturated-base type. They are commonly known as paraffin base oils because that is the final product of the fractional distillation. The higher boiling fractions of this oil are so valuable for lubricating purposes that very little of this oil is used for fuel. This oil is dark brown in color and has a greenish opalescent tinge.

The oils of the Texas and California fields are the unsaturated-base type and are known as the asphalt base oils, asphalt being the end product of distillation. After the lighter oils such as gasoline, kerosene and naphtha have been removed from the crude the residuum is not of any particular value except for fuel. The demand for gasoline therefore makes available large quantities of oil for fuel purposes. The partial distillation of the crude oil does not decrease the calorific value of the oil, in fact, the residuum known in the trade as "fuel oil" has a slightly higher calorific value per gallon than the original oil.

Fuel for domestic oil burners is divided roughly into two classes which are designated as distillate and "fuel oil." The distillate, as its name implies, is a distilled product and is usually much lighter than the "fuel oil" class which is a residue product.

Oils are usually sold by volume. When they are analyzed their heat value is reported as B. T. U. per pound. An examination of analyses shows that as the gravity of the oil decreases the heat value per pound increases. This has led some people to believe that it is more economical to purchase lighter oils in preference to the heavier fuel oil. In arriving at such a conclusion, one very important factor has been overlooked. As the heat value per pound increases, with the decreasing gravity, the number of pounds per gallon decreases so that the actual heat units in the oil per gallon, which is the purchasing unit on which the price is set, are less in the light oils than in the heavier fuel oil.

The greater heat value per gallon of fuel oil over distillate is well worth considering when they are quoted at the same price per gallon. It must be borne in mind, however, that some makes of domestic burners are not adaptable to burning anything but distillate.

The average calorific value of oils for domestic heating is slightly above 19000 B. T. U. per pound. The gravity of the oil is usually given on the Baumé scale. Distillate oils usually run from 32° to 40° Baumé while the fuel oils run from 24° to 32° Baumé. Oils below 24° Baumé are not in very common use for domestic oil heating at the present time, as it is necessary to preheat them to reduce their viscosity before they can be used successfully in the majority of the present day domestic oil burners.

Heat of the Liquid and Weight Per Cubic Foot—Continued

Temperature Deg. F.	Heat Units per lb.	Weight in lbs. per cu. ft.	Temperature Deg. F.	Heat Units per lb.	Weight in lbs. per cu. ft.	Temperature Deg. F.	Heat Units per lb.	Weight in lbs. per cu. ft.
123	90.90	61.68	153	120.86	61.12	183	150.89	60.48
124	91.90	61.67	154	121.86	61.10	184	151.89	60.46
125	92.90	61.65	155	122.86	61.08	185	152.89	60.44
126	93.90	61.63	156	123.86	61.06	186	153.89	60.41
127	94.89	61.61	157	124.86	61.04	187	154.90	60.39
128	95.89	61.60	158	125.86	61.02	188	155.90	60.37
129	96.89	61.58	159	126.86	61.00	189	156.90	60.34
130	97.89	61.56	160	127.86	60.98	190	157.91	60.32
131	98.89	61.54	161	128.86	60.96	191	158.91	60.29
132	99.88	61.52	162	129.86	60.94	192	159.91	60.27
133	100.88	61.51	163	130.86	60.92	193	160.91	60.25
134	101.88	61.49	164	131.86	60.90	194	161.92	60.22
135	102.88	61.47	165	132.86	60.87	195	162.92	60.20
136	103.88	61.45	166	133.86	60.85	196	163.92	60.17
137	104.87	61.43	167	134.86	60.83	197	164.93	60.15
138	105.87	61.41	168	135.86	60.81	198	165.93	60.12
139	106.87	61.39	169	136.86	60.79	199	166.94	60.10
140	107.87	61.37	170	137.87	60.77	200	167.94	60.07
141	108.87	61.36	171	138.87	60.75	201	168.94	60.05
142	109.87	61.34	172	139.87	60.73	202	169.95	60.02
143	110.87	61.32	173	140.87	60.70	203	170.95	60.00
144	111.87	61.30	174	141.87	60.68	204	171.96	59.97
145	112.86	61.28	175	142.87	60.66	205	172.96	59.95
146	113.86	61.26	176	143.87	60.64	206	173.97	59.92
147	114.86	61.24	177	144.88	60.62	207	174.97	59.89
148	115.86	61.22	178	145.88	60.59	208	175.98	59.87
149	116.86	61.20	179	146.88	60.57	209	176.98	59.84
150	117.86	61.18	180	147.88	60.55	210	177.99	59.82
151	118.86	61.16	181	148.88	60.53	211	178.99	59.79
152	119.86	61.14	182	149.89	60.50	212	180.00	59.76

The above data are taken from standard authorities but are not guaranteed.

PROPERTIES OF SATURATED STEAM

(Marks and Davis)

Vacuum Inches of Mercury	Absolute Pressure Lbs. per Sq. Inch	Tempera-ture, Fahren-heit	Total Heat above 32° F. In the Water, Heat-Units	Total Heat above 32° F. In the Steam, Heat-Units	Latent Heat Heat-Units	Volume, Cu. Ft. in 1 Lb. of Steam
27.89	1	101.83	69.8	1104.4	1034.6	333.0
25.86	2	126.15	94.0	1115.0	1021.0	173.5
23.82	3	141.52	109.4	1121.6	1012.3	118.5
21.79	4	153.01	120.9	1126.5	1005.7	90.5
19.75	5	162.28	130.1	1130.5	1000.3	73.33
17.71	6	170.06	137.9	1133.7	995.8	61.89
15.68	7	176.85	144.7	1136.5	991.8	53.56
13.64	8	182.86	150.8	1139.0	988.2	47.27
11.61	9	188.27	156.2	1141.1	985.0	42.36
9.57	10	193.22	161.1	1143.1	982.0	38.38
7.53	11	197.75	165.7	1144.9	979.2	35.10
5.50	12	201.96	169.9	1146.5	976.6	32.36
3.46	13	205.87	173.8	1148.0	974.2	30.03
1.42	14	209.55	177.5	1149.4	971.9	28.02
Pounds Steam Gauge						
0.0	14.70	212	180.0	1150.4	970.4	26.79
0.3	15	213.0	181.0	1150.7	969.7	26.27
1.3	16	216.3	184.4	1152.0	967.6	24.79
2.3	17	219.4	187.5	1153.1	965.6	23.38
3.3	18	222.4	190.5	1154.2	963.7	22.16
4.3	19	225.2	193.4	1155.2	961.8	21.07
5.3	20	228.0	196.1	1156.2	960.0	20.08
6.3	21	230.6	198.8	1157.1	958.3	19.18
7.3	22	233.1	201.3	1158.0	956.7	18.37
8.3	23	235.5	203.8	1158.8	955.1	17.62
9.3	24	237.8	206.1	1159.6	953.5	16.93
10.3	25	240.1	208.4	1160.4	952.0	16.30
11.3	26	242.2	210.6	1161.2	950.6	15.72
12.3	27	244.4	212.7	1161.9	949.2	15.18
13.3	28	246.4	214.8	1162.6	947.8	14.67
14.3	29	248.4	216.8	1163.2	946.4	14.19
15.3	30	250.3	218.8	1163.9	945.1	13.74
16.3	31	252.2	220.7	1164.5	943.8	13.32
17.3	32	254.1	222.6	1165.1	942.5	12.93
18.3	33	255.8	224.4	1165.7	941.3	12.57
19.3	34	257.6	226.2	1166.3	940.1	12.22
20.3	35	259.3	227.9	1166.8	938.9	11.89

Capitol Square and Smokeless Boilers

Boiler Size	Bevel Seat Pop Safety Valve Diameter, Inches: Our Standard 1923 A. S. M. E. Code with revision of Nov. 30, 1925	Bevel Seat Pop Safety Valve Diameter, Inches: Massachusetts Code (1924 Edition)
184	1	1
185	1	1¼
186	1	1½
187	1	1½
204	1¼	1¼
205	1¼	1½
206	1¼	1½
207	1¼	2
520	1¼	1½
620	1½	1½
720	1½	2
820	2	2
255	1½	2
256	1½	2
257	1½	2½
258	1½	2½
G 276	1½	2
G 277	1½	2
G 278	1½	2
G 279	2	2½
627	1½	2
727	2	2
827	2	2
927	2	2½
1027	2	2½
1127	2½	2½
1227	2½	2½ and 2
235	2	2
236	2	2½
237	2	2½
238	2	3
239	2½	3
240	2½	3
4106	2½	2½
4107	2½	2½
4108	2½	3
4109	3	3
4110	3	3 and 2
4111	3	3 and 2
740	2½	2½
840	2½	2½
940	3	2½
1040	3	2½

Capitol Square and Smokeless Boilers

Boiler Size	Bevel Seat Pop Safety Valve Diameter, Inches: Our Standard 1923 A. S. M. E. Code with revision of Nov. 30, 1925	Bevel Seat Pop Safety Valve Diameter, Inches: Massachusetts Code (1924 Edition)
1140	3	3
1240	3 and 1	3
1340	3 and 1	3
WN 276	2½	3
WN 277	2½	3 and 2
WN 278	3	3 and 2
WN 279	3 and 1	3 and 3
WN 280	3 and 1	3 and 3
WN 281	3 and 2½	3 and 3
WN 282	3 and 2½	3 and 3
WN 283	3 and 2½	3 and 3
WN 284	3 and 2½	3 and 3
750	3	3 and 2
850	3 and 1	3 and 2
950	3 and 1½	3 and 2
1050	3 and 2	3 and 3
1150	3 and 2½	3 and 3
1250	3 and 2½	3 and 3
1350	3 and 2½	3 and 3

Safety Valve Data—Capitol Winchester Boilers

	GROUP A			GROUP B			GROUP C	
	Bevel Seat Pop Safety Valve Diameter, In.			Bevel Seat Pop Safety Valve Diameter, In.			Bevel Seat Pop Safety Valve Diameter, In.	
Boiler No.	Our Standard A.S.M.E. 1923 code with revision of Nov. 30, 1925	Massachusetts Standard (1924 Edition)	Boiler No.	Our Standard A.S.M.E. 1923 code with revision of Nov. 30, 1925	Massachusetts Standard (1924 Edition)	Boiler No.	Our Standard A.S.M.E. 1923 code with revision of Nov. 30, 1925	Massachusetts Standard (1924 Edition)
24	¾	1	25	¾	1	..	...	...
31	¾	1	32	¾	1	33	¾	1
34	¾	1¼	35	¾	1¼	36	¾	1¼
45	1	1¼	46	1	1¼	47	1	1¼
55	1	1½	56	1	1½	57	1	1½
65	1	1½	66	1¼	1½	67	1¼	1½
75	1¼	2	76	1¼	2	77	1¼	2
85	1¼	2	86	1¼	2	87	1½	2

EQUIVALENT EVAPORATION AND THERMAL EFFICIENCY

TWO methods of reporting the results of steaming tests of low pressure heating boilers are in common use today.

One method used is to report results at various loads in terms of equivalent evaporation. Equivalent evaporation is the pounds of water each pound of dry fuel would evaporate into steam at standard atmospheric pressure if the feed water temperature were 212° F. When results are reported in terms of equivalent evaporation the heat value of the dry fuel must be given because the evaporation varies with the heat value of the fuel used.

The other method used is to report the thermal efficiency at various loads. Thermal efficiency is the percentage of the heat in the fuel that the boiler can make available for heating purposes.

Each method of reporting tests has some advantage that the other does not possess. In order to give the advantages of both systems it is sometimes desirable to be able to convert quickly from one to the other. The mathematical relationship between these two figures is simple and it is possible to convert them when the heating value of the dry fuel is known. In order to eliminate this computation and thus facilitate the conversion, the graph on the opposite page has been prepared. Equivalent evaporation per pound of dry fuel is plotted on the horizontal axis and thermal efficiency on the vertical axis. The sloping lines represent fuels of various heat values and cover the ranges generally encountered in coal and oil fuels. The method of using the graph is illustrated by the two examples that follow:

EXAMPLE No. 1

Equivalent evaporation—9.8 pounds.

Heat value of coal used—13,000 B. T. U. per lb. of dry coal.

What is the thermal efficiency?

Find the point on the horizontal axis corresponding to an evaporation of 9.8. Follow this line vertically to its intersection with the line marked 13,000 B. T. U. From this intersection follow the dotted horizontal line to the left to its intersection with the vertical axis which is at 73% efficiency.

EXAMPLE No. 2

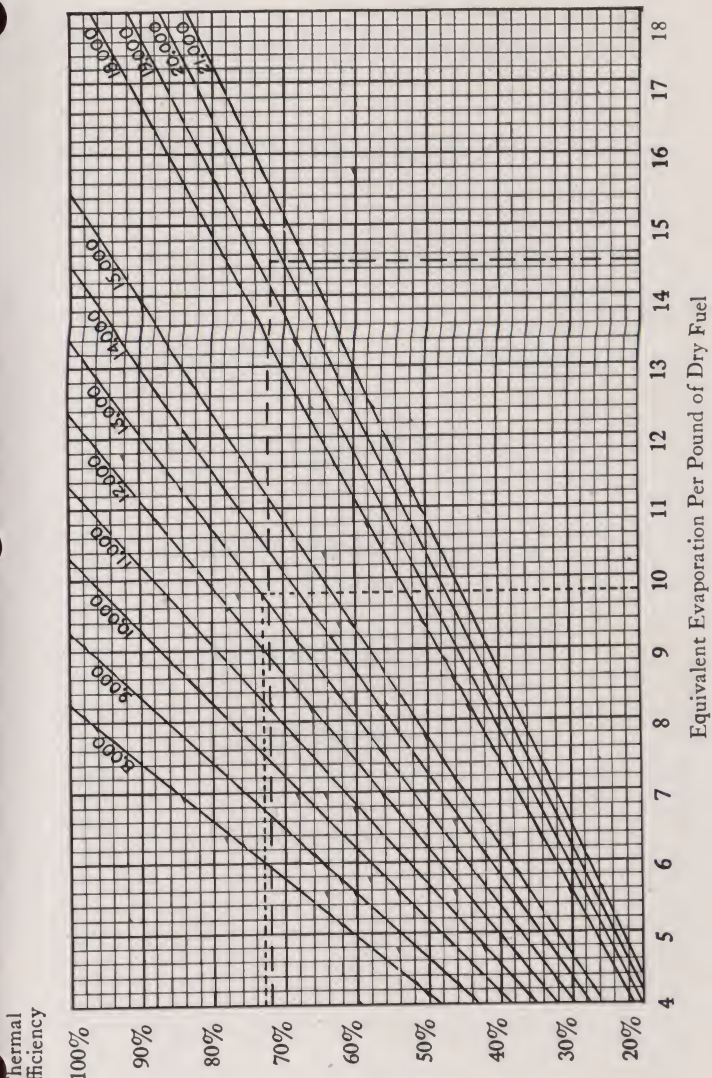
Thermal efficiency—72%

Heat value of the oil—19,500 B. T. U.

What equivalent evaporation was obtained?

Imagine a line drawn midway between the lines marked 19,000 B. T. U. and 20,000 B. T. U. Such a line would represent a heat value of 19,500 B. T. U. per pound. Now find the point 72% on the vertical axis and follow the dashed line horizontally to its intersection with the imaginary line corresponding to a heat value of 19,500 B. T. U. From this intersection follow the dashed line vertically downward to the horizontal axis. The intersection is at 14.5 pounds, equivalent evaporation.

EQUIVALENT EVAPORATION AND THERMAL EFFICIENCY



Number of gallons in round tanks—Diameter, Inches

Depth or Length	18-inch	24-inch	30-inch	36-inch	42-inch	48-inch	54-inch	60-inch	66-inch	72-inch
1 Inch	1.10	1.96	3.06	4.41	5.99	7.83	9.91	12.24	14.81	17.62
1 ft.	13.	23.	37.	53.	72.	94.	119.	147.	178.	211.
1½ ft.	20.	35.	55.	79.	108.	141.	179.	220.	267.	317.
2 ft.	26.	47.	73.	106.	144.	188.	238.	294.	355.	423.
2½ ft.	33.	59.	92.	132.	180.	235.	298.	367.	444.	529.
3 ft.	40.	71.	110.	159.	216.	282.	357.	441.	533.	634.
3½ ft.	46.	82.	129.	185.	252.	329.	417.	514.	622.	740.
4 ft.	53.	94.	147.	211.	288.	376.	476.	587.	711.	846.
4½ ft.	59.	106.	165.	238.	324.	423.	536.	661.	800.	952.
5 ft.	66.	118.	183.	264.	360.	470.	597.	734.	889.	1157.
5½ ft.	73.	129.	202.	291.	396.	517.	657.	808.	977.	1263.
6 ft.	79.	141.	220.	317.	432.	564.	714.	881.	1066.	1369.
7 ft.	92.	164.	257.	370.	504.	658.	833.	1028.	1244.	1580.
8 ft.	106.	188.	294.	423.	576.	752.	952.	1175.	1422.	1792.
9 ft.	119.	212.	330.	476.	648.	846.	1071.	1322.	1599.	2003.
10 ft.	132.	235.	367.	529.	720.	940.	1190.	1469.	1777.	2115.
12 ft.	157.	282.	440.	634.	864.	1128.	1428.	1762.	2133.	2537.
14 ft.	185.	329.	514.	740.	1008.	1316.	1666.	2056.	2488.	2960.
16 ft.	211.	376.	587.	846.	1152.	1504.	1904.	2350.	2844.	3383.
18 ft.	238.	423.	661.	952.	1296.	1692.	2142.	2644.	3199.	3806.
20 ft.	264.	470.	734.	1057.	1440.	1880.	2380.	2937.	3554.	4229.

One-inch depth is given to facilitate figuring intermediate depths.

For tanks having a diameter other than those given in the table, multiply the square of the diameter in inches by the length in feet and multiply this product by 0.0408 to obtain tank capacity in U. S. gallons. When both diameter and length are given in inches, the capacity in U. S. gallons equals 0.0034 x d^2L.

Pressure for Different Heads of Water at 62 Degrees Fahrenheit

1 foot head=0.43302 lb. per sq. in. 1 inch head=0.5774 ounces per sq. in.

Inches of Water to Ounces per Square Inch

Head, inches	1	2	3	4	5	6	7	8	9	10	11	12
Pressure, inches	.577	1.15	1.73	2.31	2.89	3.46	4.04	4.62	5.20	5.77	6.35	6.93

Feet of Water to Pounds per Square Inch

Head, feet	0	1	2	3	4	5	6	7	8	9
0	....	0.433	0.866	1.299	1.732	2.165	2.598	3.031	3.464	3.897
10	4.330	4.763	5.196	5.629	6.062	6.495	6.928	7.361	7.794	8.227
20	8.660	9.093	9.526	9.959	10.392	10.825	11.258	11.691	12.124	12.557
30	12.990	13.423	13.856	14.289	14.722	15.155	15.588	16.021	16.454	16.887
40	17.320	17.753	18.186	18.619	19.052	19.485	19.918	20.351	20.784	21.217
50	21.650	22.083	22.516	22.949	23.382	23.815	24.248	24.681	25.114	25.547
60	25.980	26.413	26.846	27.279	27.712	28.145	28.578	29.011	29.444	29.877
70	30.310	30.743	31.176	31.609	32.042	32.475	32.908	33.341	33.774	34.207
80	34.640	35.073	35.506	35.939	36.372	36.805	37.238	37.671	38.104	38.537
90	38.970	39.403	39.836	40.269	40.702	41.135	41.568	42.001	42.436	42.867

Example: For head of 18 ft., pressure is 7.794 lbs. per sq. in.

Head of Water 62° Fahrenheit Corresponding to Different Pressures

1 pound per sq. in. = 2.3095 feet head. 1 ounce per sq. in. = 1.732 in. of water

Ounces per Square Inch to Inches of Water

Pressure, ounces	1	2	3	4	5	6	7	8
Head, inches	1.73	3.46	5.20	6.93	8.66	10.39	12.12	13.85
Pressure, ounces	9	10	11	12	13	14	15	16
Head, inches	15.59	17.32	19.05	20.78	22.52	24.25	25.98	27.71

Pounds per Square Inches to Feet of Water

Pressure	0	1	2	3	4	5	6	7	8	9
0	....	2.31	4.62	6.93	9.24	11.55	13.86	16.17	18.48	20.78
10	23.09	25.40	27.71	30.02	32.33	34.64	36.95	39.26	41.57	43.88
20	46.19	48.50	50.81	53.12	55.43	57.74	60.05	62.36	64.66	66.97
30	69.28	71.59	73.90	76.21	78.52	80.83	83.14	85.45	87.76	90.07
40	92.38	94.69	97.00	99.31	101.62	103.93	106.24	108.55	110.85	113.16
50	115.47	117.78	120.09	122.40	124.71	127.02	129.33	131.64	133.95	136.26
60	138.57	140.88	143.19	145.50	147.81	150.12	152.42	154.73	157.04	159.35
70	161.66	163.97	166.28	168.59	170.90	173.21	175.52	177.83	180.14	182.45
80	184.76	187.07	189.38	191.69	194.00	196.31	198.61	200.92	203.23	205.54
90	207.85	210.16	212.47	214.78	217.09	219.40	221.71	224.02	226.33	228.64

Example: For pressure of 27 lbs. per sq. in., head is 62.36 feet.

Measures of Pressure and Weight

1 lb. per square inch =	144	lbs. per square foot
	2.0355	inches of mercury at 32 degrees Fahr.
	2.0416	inches of mercury at 62 degrees Fahr.
	2.309	ft. of water at 62 degrees Fahr.
	27.71	inches of water at 62 degrees Fahr.
1 Atmosphere (14.7 lbs. per sq. in.) =	2116.3	lbs. per square foot
	33.947	ft. of water at 62 degrees Fahr.
	30	inches of mercury at 62 degrees Fahr.
	29.922	inches of mercury at 32 degrees Fahr.
	760	millimetres of mercury at 32 degrees Fahr.
1 Foot of Water at 62 degrees Fahr. =	.433	lbs. per square inch
	62.355	lbs. per square foot
1 Inch of Mercury at 62 degrees Fahr. =	.491	lb. or 7.86 oz. per sq. in.
	1.132	ft. of water at 62 degrees Fahr.
	13.58	inches of water at 62 degrees Fahr.

Measure of Solidity, Liquid Measure

1728 cubic inches = 1 cubic foot
27 cubic feet = 1 cubic yard

4 gills make 1 pint
2 pints make 1 quart
4 quarts make 1 gallon
31½ gallons make 1 barrel

Circular Measure

60 Seconds″ = 1 Minute′
60 Minutes′ = 1 Degree°
90 Degrees° = 1 Quadrant
360 Degrees° = 1 Circumference

Measure of Surface

144 Sq. In. } = 1 Sq. Ft.
183.35 Cir. In. }
9 Sq. Ft. = 1 Sq. Yd.
30¼ Sq. Yds. } = 1 Sq. Rd.
272¼ Sq. Ft. }

Square Inches x .007 = Square Feet
Cubic Inches x .00058 = Cubic Feet

Weights and Equivalent Volumes

1 Cubic Inch of Cast Iron	Weighs	0.260 Pounds
1 Cubic Inch of Wrought Iron	Weighs	0.278 Pounds
1 Cubic Foot of Water (at 62° F.)	Weighs	62.355 Pounds
1 U. S. Gallon (at 62° F.)	Weighs	8.336 Pounds
1 Imperial Gallon (at 62° F.)	Weighs	10.000 Pounds
1 U. S. Gallon	Equals	231.000 Cubic Inches
1 Imperial Gallon	Equals	277.274 Cubic Inches
1 Cubic Foot	Equals	7.480 U. S. Gallons

1 Pound of Steam (at 212°F. and 14.7 lb. per Sq. In.) Equals 26.79 Cubic Ft.
1 Pound of Air (at 32°F. and 14.7 lb. per Sq. In.) Equals 12.387 Cubic Ft.

1/64	.0156	17/64	.2656	33/64	.5156	49/64	.7656
1/32	.0312	9/32	.2812	17/32	.5312	25/32	.7812
3/64	.0468	19/64	.2969	35/64	.5469	51/64	.7969
1/16	.0625	5/16	.3125	9/16	.5625	13/16	.8125
5/64	.0781	21/64	.3281	37/64	.5781	53/64	.8281
3/32	.0937	11/32	.3437	19/32	.5937	27/32	.8437
7/64	.1093	23/64	.3594	39/64	.6094	55/64	.8594
1/8	.125	3/8	.375	5/8	.625	7/8	.875
9/64	.1406	25/64	.3906	41/64	.6406	57/64	.8906
5/32	.1562	13/32	.4062	21/32	.6562	29/32	.9062
11/64	.1718	27/64	.4219	43/64	.6719	59/64	.9219
3/16	.1875	7/16	.4375	11/16	.6875	15/16	.9375
13/64	.2031	29/64	.4531	45/64	.7031	61/64	.9531
7/32	.2187	15/32	.4687	23/32	.7187	31/32	.9687
15/64	.2344	31/64	.4844	47/64	.7344	63/64	.9844
1/4	.25	1/2	.5	3/4	.75	1	1.0

Table of the Weights of Galvanized Iron Pipe in Pounds per Running Foot

Diam. of Pipe Inches	GAUGE OF IRON					Diam. of Pipe Inches	GAUGE OF IRON				
	No. 24	No. 22	No. 20	No. 18	No. 16		No. 24	No. 22	No. 20	No. 18	No. 16
5	1 3/4	2	2 1/2	3 3/8	4	28	9 1/2	11 3/8	14	18	21 1/2
6	2 1/8	2 1/2	3	4	4 3/4	30	10	12 1/4	15	19 3/8	23
7	2 1/2	3	3 1/2	4 5/8	5 1/2	32	.....	13 1/8	16	20 3/4	24 5/8
8	2 7/8	3 3/8	4	5 1/4	6 3/4	34	.....	14	17	22	26 1/4
9	3 1/4	3 3/4	4 1/2	5 7/8	7	36	.....	15	18	23 3/4	27 7/8
10	3 1/2	4	5	6 1/2	7 5/8	38	.....	16	19	24 1/2	29 1/2
11	3 3/4	4 1/4	5 1/2	7	8 1/4	40	.....	17	20	26 1/4	31 1/4
12	4	4 5/8	6	7 1/2	9	42	.....	.....	21	28	33
13	4 1/4	5 1/8	6 1/2	8 3/8	10	44	.....	.....	22	29 3/4	35
14	4 5/8	5 1/2	7	8	11	46	.....	.....	23	31 1/2	37
15	5	6	7 1/2	9 5/8	12	48	.....	.....	24	33 1/4	39
16	5 1/2	6 1/2	8	10 1/4	13	50	.....	.....	25	35	41
18	6	7 1/4	9	11 1/2	14 1/4	52	.....	.....	26	36 3/4	43
20	6 1/2	8	10	12 3/4	15 1/2	54	.....	.....	27	38 1/2	45
22	7 1/4	8 3/4	11	14	16 3/4	56	.....	.....	28	40 1/4	47
24	8	9 5/8	12	15 1/4	18 1/2	58	.....	.....	29	42	49
26	8 3/4	10 1/2	13	16 1/2	20	60	.....	.....	30	43 3/4	51

In above table allowance has been made for laps, trimmings, rivets and solder.

Showing the Loss in Conductivity of Boiler Plate Due to Difference in Thickness of Soot Deposit

Thickness of Soot	Loss Per Cent
Clean	0.0
1/32″	9.5
1/16″	26.2
1/8″	45.2
3/16″	69.0

Proceedings, Institute of Marine Engineers, January 6, 1908.

Diameter	Area	Diameter	Area	Diameter	Area	Diameter	Area
1/8	0.0123	10	78.54	30	706.86	65	3318.3
1/4	0.0491	10 1/2	86.59	31	754.76	66	3421.2
3/8	0.1104	11	95.03	32	804.24	67	3535.6
1/2	0.1963	11 1/2	103.86	33	855.30	68	3631.6
5/8	0.3068	12	113.09	34	907.92	69	3739.2
3/4	0.4418	12 1/2	122.71	35	962.11	70	3848.4
7/8	0.6013	13	132.73	36	1017.8	71	3959.2
1	0.7854	13 1/2	143.13	37	1075.2	72	4071.5
1 1/8	0.9940	14	153.93	38	1134.1	73	4185.4
1 1/4	1.227	14 1/2	165.13	39	1194.5	74	4300.8
1 3/8	1.484	15	176.71	40	1256.6	75	4417.8
1 1/2	1.767	15 1/2	188.69	41	1320.2	76	4536.4
1 5/8	2.073	16	201.06	42	1385.4	77	4656.6
1 3/4	2.405	16 1/2	213.82	43	1452.2	78	4778.3
1 7/8	2.761	17	226.98	44	1520.5	79	4901.6
2	3.141	17 1/2	240.52	45	1590.4	80	5026.5
2 1/4	3.976	18	254.46	46	1661.9	81	5153.0
2 1/2	4.908	18 1/2	268.80	47	1734.9	82	5281.0
2 3/4	5.939	19	283.52	48	1809.5	83	5410.6
3	7.068	19 1/2	298.64	49	1885.7	84	5541.7
3 1/4	8.295	20	314.16	50	1963.5	85	5674.5
3 1/2	9.621	20 1/2	330.06	51	2042.8	86	5808.8
3 3/4	11.044	21	346.36	52	2123.7	87	5944.6
4	12.566	21 1/2	363.05	53	2206.1	88	6082.1
4 1/2	15.904	22	380.13	54	2290.2	89	6221.1
5	19.635	22 1/2	397.60	55	2375.8	90	6361.7
5 1/2	23.758	23	415.47	56	2463.0	91	6503.9
6	28.274	23 1/2	433.73	57	2551.7	92	6647.6
6 1/2	33.183	24	452.39	58	2642.0	93	6792.9
7	38.484	24 1/2	471.43	59	2733.9	94	6939.8
7 1/2	44.178	25	490.87	60	2827.4	95	7088.2
8	50.265	26	530.93	61	2922.4	96	7238.2
8 1/2	56.745	27	572.55	62	3019.0	97	7389.8
9	63.617	28	615.75	63	3117.2	98	7542.9
9 1/2	70.882	29	660.52	64	3216.9	99	7697.7

To compute the area of a diameter greater than any in the above table:

RULE—Divide the dimension by 2, 3 4, etc., if practicable, until it is reduced to a quotient to be found in the table, then multiply the tabular area of the quotient by the square of the factor. The product will be the area required.

EXAMPLE—What is area of diameter of 150? 150÷5=30. Tabular area of 30=706.88 which x 25=17,671.5 area required.

To obtain area of circle, square diameter and multiply by .7854 or square the radius and multiply by 3.1416.

Diameter	Circumference	Diameter	Circumference	Diameter	Circumference	Diameter	Circumference
1/8	.3927	10	31.41	30	94.24	65	204.2
1/4	.7854	10½	32.98	31	97.38	66	207.3
3/8	1.178	11	34.55	32	100.5	67	210.4
1/2	1.570	11½	36.12	33	103.6	68	213.6
5/8	1.963	12	37.69	34	106.8	69	216.7
3/4	2.356	12½	39.27	35	109.9	70	219.9
7/8	2.748	13	40.84	36	113.0	71	223.0
1	3.141	13½	42.41	37	116.2	72	226.1
1⅛	3.534	14	43.98	38	119.3	73	229.3
1¼	3.927	14½	45.55	39	122.5	74	232.4
1⅜	4.319	15	47.12	40	125.6	75	235.6
1½	4.712	15½	48.69	41	128.8	76	238.7
1⅝	5.105	16	50.26	42	131.9	77	241.9
1¾	5.497	16½	51.83	43	135.0	78	245.0
1⅞	5.890	17	53.40	44	138.2	79	248.1
2	6.283	17½	54.97	45	141.3	80	251.3
2¼	7.068	18	56.54	46	144.5	81	254.4
2½	7.854	18½	58.11	47	147.6	82	257.6
2¾	8.639	19	59.69	48	150.7	83	260.7
3	9.424	19½	61.26	49	153.9	84	263.8
3¼	10.21	20	62.83	50	157.0	85	267.0
3½	10.99	20½	64.40	51	160.2	86	270.1
3¾	11.78	21	65.97	52	163.3	87	273.3
4	12.56	21½	67.54	53	166.5	88	276.4
4½	14.13	22	69.11	54	169.6	89	279.6
5	15.70	22½	70.68	55	172.7	90	282.7
5½	17.27	23	72.25	56	175.9	91	285.8
6	18.84	23½	73.82	57	179.0	92	289.0
6½	20.42	24	75.39	58	182.2	93	292.1
7	21.99	24½	76.96	59	185.3	94	295.3
7½	23.56	25	78.54	60	188.4	95	298.4
8	25.13	26	81.68	61	191.6	96	301.5
8½	26.70	27	84.82	62	194.7	97	304.7
9	28.27	28	87.96	63	197.9	98	307.8
9½	29.84	29	91.10	64	201.0	99	311.0

To compute the circumference of a diameter greater than any in the above table:

RULE—Divide the dimension by 2, 3, 4, etc., if practicable, until it is reduced to a dimension to be found in the table. Take the tabular circumference of this diameter, multiply it by 2, 3, 4, etc., according as it was divided, and the product will be the circumference required.

EXAMPLE—What is the circumference of a diameter of 125? 125 ÷ 5 = 25. Tabular circumference of 25 = 78.54; 78.54 x 5 = 392.7, circumference required.

To find the diameter of a circle when circumference is given, multiply the given circumference by .31831.

To find the circumference of a circle when diameter is given, multiply the given diameter by 3.1416.

Special Notice

PLEASE bear in mind the following in using the telegraph code:

1. Telegraph only when the matter is urgent. When a letter will answer the purpose, it is *surer*, as errors in transmission cannot then occur.

2. Where a blank occurs in a sentence, the word or words supplying the blank must *always follow* the code word of the sentence.

3. Except in cablegrams, ten words are as cheap as any number less. Avoid code where the matter can be covered in ten words without it.

4. Write plainly and begin each code word with a capital letter.

Quotations and Correspondence

Answer by first mail.................................Ablative
At what price and how soon can you furnish.............Abluvion
Best carload freight quoted is.........................Abnodate
Best less-than-carload freight rate quoted is..........Abradant
Do not understand the meaning of.......................Abscissa
Full particulars in letter of..........................Abyssal
Have received no reply to our letter of................Acadian
Have received no reply to our telegram of..............Acanthus
Have written...Acceder
Referring to our letter of.............................Accolade
Referring to our telegram of...........................Accordian
Referring to telephone conversation today..............Accumbent
Referring to your letter of............................Acicular
Referring to your telegram of..........................Acinous
What is carload freight rate to........................Aclintic
What is less-than-carload freight rate to..............Acoustic
Wire branch direct.....................................Acrobat
Wire customer direct...................................Acrostic
Wire flue size at once.................................Actinoid
Wire reply quick.......................................Actress

Orders and Shipments

Add to our order No....................................Baboon
Can ship immediately...................................Bacteria
Can you ship immediately...............................Backlog
Change our order No.—— to read.........................Backhand
Do not find any order from you.........................Backslide
Do not hold for other orders but rush without delay....Bagasse
Duplicate our order No.................................Bagnio
First of next week.....................................Bailer
Hold order No.—— for instructions......................Balata

Include in car for——which leaves . . . . Balladry
Include in first car for . . . . Balmoral
Latter part of this week . . . . Banality
Latter part of next week . . . . Bandoleer
Must have——at once. Cannot wait for . . . . Banquet
Omit——from our order No. . . . . Barbate
Order No.——has not been shipped . . . . Barbaric
Referring to our order . . . . Barbecue
Referring to your order . . . . Bargainer
Routing on your shipment is as follows . . . . Baritone
Send shipping tickets to . . . . Barnacle
Send us bill of lading covering our order No. . . . . Barricade
Shall we forward as small lot . . . . Bartizan
Ship as small lot unless car going at once . . . . Bashfully
Ship by best route . . . . Basswood
Ship by first boat . . . . Batterer
Ship by same route as our order No. . . . . Bavarian
Ship immediately and follow with tracer . . . . Bayberry
Ship immediately by express collect . . . . Beadword
Ship immediately by express prepaid . . . . Beastlike
Ship immediately by freight collect . . . . Beddable
Ship immediately by freight prepaid . . . . Bedspread
Ship immediately by parcel post . . . . Befuddle
Ship what you can at once, balance soon as possible . . . . Befriend
Ship with draft attached to bill of lading . . . . Begonia
Shipping instructions for order No. . . . . Belonite
Substitute on our order No. . . . . Benedict
We cannot furnish . . . . Berretta
We cannot promise definitely but will give best attention . . . Beverage
We have no car going for——days . . . . Bewilder
When and by what route did you ship our order . . . . Bewitch
When can you make shipment . . . . Bezetta
When will car be shipped containing our order . . . . Biceps
When will you ship our order . . . . Biferous
Will mail you today bill of lading covering order No. . . . . Billiards
Will ship in about . . . . Billeken
Will ship your order . . . . Bimanous
Wire instructions . . . . Bindweed
Wire routing on shipment of our order . . . . Biologist
Wire shipping date, car number and routing on our order No. Bitterly
Wire trace our order No. . . . . Bivalent
Your order does not specify steam or water. Wire which is wanted . . . . Bivouac

Numerals

To be used when giving quantities, order numbers, weights, dollars and cents, etc.

1	ON	6	SI	Repeat	X
2	TO	7	VE	Dollars	DO
3	TH	8	EI	Feet	FE
4	FO	9	NI	Discount	Dis
5	IV	0	OH		

Examples

10155. 1-on 0-oh 1-on 5-iv 5-x (used instead of repeating iv)—onohonivx.

$146.80. 1-on 4-fo 6-si dollars-do 8-ei 0-oh—onfosidoeioh.

1,100 feet. 1-on 1-x 0-oh 0-x feet-fe—onxohxfe.

14,000. 1-on 4-fo 0-oh 0-x 0-oh (oh is repeated to avoid having two x's)—onfoohxoh.

In writing telegram use all small letters and join together to make one complete word. To avoid confusion on long numbers it is sometimes advisable to print the characters. In that case use all capitals, viz.: 1468—ONFOSIEI.

An easy method of deciphering can be used by separating every two letters, starting at the left, except where x appears.

ivohxdotosi—iv oh x do to si—500 dollars 26 $500.26.

Capitol Red Cap Boilers

No.	Steam	Water
17-4	Dabbling	Dapple
17-5	Dagger	Daring
19-4	Daffodil	Darky
19-5	Dairyman	Darling
20-4	Daisy	Darnel
20-5	Dally	Daub
22-4	Damask	Dawdle
22-5	Damned	Deacon
25-4	Damsel	Deanship
25-5	Dandelion	Debonair
25-6	Dander	Decalet
28-4	Dandruff	Decanter
28-5	Danebrog	Decorous
28-6	Danseuse	Deerhound

Capitol Red Head Boilers

No.	Steam	Water
19	Delphian	Denizen
21	Demagog	Dendrite
23	Demantoid	Dentated
25	Demeanor	Deplume

Capitol Red Top Boilers
Standard—All Fuels

No.	Steam	Water
A-6	Depletory	Dialectic
A-7	Deplorer	Dialogist
A-8	Deponent	Dialysis
A-9	Depolish	Diamicton
A-10	Depopulate	Diamide
A-11	Deputator	Dianthine
B-6	Derby	Diandrous
B-7	Derelict	Diaphane
B-8	Dermal	Diapason
B-9	Dervish	Dibstone
B-10	Desecrate	Diegesis
B-11	Desertful	Dietarian
B-12	Dewiness	Dielectric
C-12	Dewberry	Dietitian
C-14	Dexterous	Diffident
C-16	Dextronal	Digitalis
C-18	Diabolo	Dignation
C-20	Diaconate	Dignified
C-22	Diagraph	Digress

Capitol Red Top Boilers
Smokeless Type for Soft Coal

No.	Steam	Water
B-9	Digonous	Diplomat
B-10	Digression	Diplanar
B-11	Dihedral	Dirempt
B-12	Dihelium	Disabuse
B-13	Dinoceras	Disagio
B-14	Dinosaur	Disagreer
C-14	Dinocrates	Disaffect
C-16	Dinomic	Disaffirm
C-18	Diodorus	Disburser
C-20	Diodon	Discerner
C-22	Diogenes	Disciform
C-24	Diolefine	Discoidal

Capitol Round Boilers

No.	Steam	Water
17-4	Discusser	Dolorific
17-5	Disponer	Dolphin
19-4	Diurnally	Domain
19-5	Diuretic	Domesticate
20-4	Divertive	Domicile
20-5	Dividual	Dominate
20-6	Dodecane	Domineer
22-4	Dockyard	Dominie
22-5	Docimassy	Donator
22-6	Dochmius	Dongola
25-4	Doggerman	Donnism
25-5	Dogmatic	Doomsday
25-6	Dogrose	Dorian
28-4	Dokamok	Doric
28-5	Dolabra	Dormer
28-6	Dolomite	Dotage

Capitol Round Boilers
Low Water Line Type

No.	Steam	Water
LW19-4	Dotard	Dovecote
LW20-4	Doublet	Dowager
LW22-4	Doubloon	Dowdiness
LW22-5	Doughty	Downcast

Capitol Square Sectional Boilers

No.	Steam	Water
204	Eaglet	Embarrass
205	Earldom	Embellish
206	Earmark	Emblazon
207	Earthnut	Embolite
G276	Earwig	Embosser
G277	Eavesdrop	Emersion
G278	Ebullient	Emigrate
G279	Eburnine	Eminence
235	Ecboline	Emissary
236	Echinate	Emphasis

Capitol Square Sectional Boilers—Continued

No.	Steam	Water
237	Echoless	Empirical
238	Ecliptic	Emptiness
239	Ecstatic	Emulation
240	Edelweiss	Emulsify
4106	Edifying	Enactment
4107	Educative	Enchanted
4108	Efflation	Encompass
4109	Effusion	Encumber
4110	Eglantine	Endearing
4111	Egyptian	Endlessly
WN276	Ejaculate	Enduring
WN277	Elective	Energetic
WN278	Elegance	Enfilade
WN279	Elephant	Enlighten
WN280	Elevated	Entangle
WN281	Eligible	Environs
WN282	Elongate	Epicurean
WN283	Eloquent	Equipoise
WN284	Elusively	Eradicate

Capitol Smokeless Boilers

No.	Steam	Water
520	Eraser	Eulogist
620	Erebus	Eunuch
720	Erethism	Euphonic
820	Ergmeter	Eureka
627	Ermine	Evacuate
727	Erostrate	Evangel
827	Errantry	Evasion
927	Erroneous	Evening
1027	Erudition	Eventide
1127	Escalade	Eventuate
1227	Eschew	Everglade
740	Escutcheon	Evidential
840	Eskimo	Evincible
940	Esparto	Evolutive
1040	Espousal	Exaction
1140	Esquire	Excelsior
1240	Establish	Exchequer
1340	Estovers	Excitant
750	Estuary	Exclave
850	Eternal	Exclusive
950	Ethereal	Excoriate
1050	Ethmoid	Excreta
1150	Ethylene	Excursion
1250	Etymon	Execrate
1350	Euchre	Exegesis

Capitol Red Cap Boilers, Oil Burning Type

No.	Steam	Water
017-5	Fable	Faithful
019-5	Fabulous	Falchion
020-5	Facet	Fallacy
022-5	Facial	Falsehood
025-5	Faction	Fame
025-6	Fad	Family
028-5	Fail	Famish
028-6	Faint	Fanatic

Capitol Red Top Boilers, Oil Burning Type

No.	Steam	Water
A-06	Fandango	Ferocious
A-07	Fang	Fertile
A-08	Fantasia	Festal
A-09	Farina	Fetch
A-010	Farrago	Fetlock
A-011	Fascinate	Feudal
B-07	Fastening	Fiddle
B-08	Fastland	Fido
B-09	Father	Finest
B-010	Fatigue	Fingen
B-011	Fauna	Fireman
B-012	Fawn	Firm
B-013	Fealty	Flank
B-014	Feasible	Flare
C-012	Febrile	Flatfish
C-014	Federal	Flattery
C-016	Feldspar	Flaunt
C-018	Felony	Flaxseed
C-020	Felucca	Fleabane
C-022	Fender	Fleece
C-024	Ferment	Fleeting

Capitol Square Sectional Boilers, Oil Burning Type

No.	Steam	Water
0205	Flesh	Flyblow
0206	Flexion	Foam
0207	Flicker	Focal
0208	Flight	Focus
0209	Flimsily	Fodder
0210	Flinch	Foible
0211	Flinty	Folderol
0235	Flipper	Foliage
0236	Floater	Follia

Capitol Square Sectional Boilers, Oil Burning Type—Con't

No.	Steam	Water
0237	Floral	Folly
0238	Flossy	Foment
0239	Flotilla	Fomes
0240	Flounce	Fondu
0241	Flounder	Fontal
0242	Floury	Foolery
0243	Flower	Fooling
0411	Flowing	Foolscap
0412	Fluff	Football
0413	Fluke	Footman
0414	Flunk	Footpad
WN 0280	Fluoric	Forage
WN 0281	Fluorine	Foray
WN 0282	Flushing	Forbid
WN 0283	Flute	Forceps
WN 0284	Flutina	Forearm
WN 0285	Flutter	Forebow
WN 0286	Fluxion	Forecast

Capitol Round Boilers, Oil Burning Type

No.	Steam	Water
017-5	Forecastle	Forerun
019-5	Foreclose	Foresail
019-6	Forefather	Foreshore
020-5	Forego	Forest
020-6	Forehead	Forestall
022-5	Foreign	Forestay
022-6	Foreland	Forester
025-5	Forelock	Foretop
025-6	Foreman	Forewind
028-5	Foremost	Forfeit
028-6	Forensic	Forfend

Capitol Radiators

		3 Tube		
36″ Gabardine	30″ Gabion	26″ Gable	23″ Gablet	20″ Gadfly
		4 Tube		
37″ Gadwall	32″ Gaelic	26″ Gageable	23″ Gagger	20″ Gahnite
		5 Tube		
37″ Gaiety	32″ Gaiter	26″ Galactic	23″ Galacto	20″ Galatea
		6 Tube		
37″ Galbanum	32″ Galena	26″ Galipot	23″ Gallant	20″ Galleas
		7 Tube		
	20″ Galleon	16½″ Gallery	13″ Gallic	

Capitol Hospital Radiators

3 Tube

36″	30″	26″	23″	20″
Galling	Gallipot	Gallium	Gallivat	Galloon

5 Tube

37″	32″	26″	23″	20″
Gallopade	Gallows	Gallstone	Galosh	Galvanic

Capitol Mural Radiators

1 Tube

17″	23″
Galvanism	Gambier

2 Tube

17″	20″	23″
Gambit	Gambler	Gamboge

3 Tube

17″	20″	23″
Gambol	Gambrel	Gambroon

4 Tube

17″	20″	23″
Gamecock	Gamefowl	Gameful

5 Tube

17″	23″
Gamesome	Gamete

Triton Wall Radiators

No.	Steam	Water
5A	Gammon	Gannet
7A	Gamut	Gantlet
9A	Gander	Gaol
7B	Ganger	Garage
9B	Ganglion	Garbage

Triton Bathroom Wall Radiators

No.	Steam	Water
3A	Gangrene	Garboard
3½A	Gangway	Garcon

Number of Radiator Sections

2......Oatmeal
3......Obdurate
4......Obeisant
5......Obelisk
6......Obesity
7......Obfuscate
8......Objective
9......Oblation
10......Oblique
11......Oblivion
12......Oblong
13......Oboe
14......Obscurity
15......Obsequy
16......Observance
17......Obsession
18......Obstacle
19......Obstinate
20......Obtrude
21......Obtumdent
22......Obvention
23......Obvolute
24......Occasional
25......Occident
26......Occult
27......Occupation
28......Octant
29......Octillion
30......Octonary
31......Occular
32......Oddity
33......Odeon
34......Odorate
35......Offertory
36......Offspring

Indirect Radiators

Pin Indirect, steam, 10 feet	Pacha
Pin Indirect, water, 10 feet	Pacifier
Pin Indirect, steam, 15 feet	Packet
Pin Indirect, water, 15 feet	Paddle
Pin Indirect, steam, 20 feet	Paddock
Pin Indirect, water, 20 feet	Padrone
Not assembled	Pagan
Assembled with push nipples	Pageant
Assembled with right and left screw nipples	Paginal
Arranged for wall brackets	Pagoda

Pantry Radiators

No. 1	No. 2	No. 3	No. 4	No. 5
Pailful	Painter	Pajamas	Paladin	Palatal

Triton Adjustable Wall Brackets

Style N	Palitine	Style O (Horizontal)	Palaver
Style O (Vertical)	Palestra		

Wall Radiator Brackets

A6	Palette	B9½	Palpable
A8	Palfrey	C	Pampas
A10	Palisade	D	Pampero
A12	Pallet	E	Panacea
A14	Pallium	F	Panada
A16	Palmate	G	Pancake
B5½	Palmist	H	Pandean
B7½	Palmitin	I	Pandect

Adjustable Concealed Brackets

3 Tube	Pannier	5 Tube	Panorama
4 Tube	Panoply	6 Tube	Panslavic

Radiator Miscellanies

Triton Wall Boxes	Pantaloon
Capitol 5 Tube Box Bases	Panthiest
Washed and cleaned for vacuum system	Pantheon

Tapping Instructions

¾-inch single pipe	Tablature	1½ x 1½-inch	Tamarind
¾ x ¾-inch	Tableau	1½ x 1¼-inch	Tambourine
¾ x ½-inch	Tabloid	1½ x 1-inch	Tame
1-inch single pipe	Taboret	1½ x ¾-inch	Tamkin
1 x 1-inch	Taciturn	1½ x ½-inch	Tandems
1 x ¾-inch	Tactician	¾ x ¾-inch eccentric	Tangerine
1 x ½-inch	Taffeta	¾ x ½-inch eccentric	Tantalize
1¼-inch single pipe	Tagal	1 x 1-inch eccentric	Tantalus
1¼ x 1¼-inch	Tailoress	1 x ¾-inch eccentric	Tantara
1¼ x 1-inch	Taintless	1 x ½-inch eccentric	Tantrum
1¼ x ¾-inch	Talaria	1½ x 1-inch eccentric	Teething
1¼ x ½-inch	Talmud	1½ x ¾-inch eccentric	Telluric
1½-inch single pipe	Tamale	1½ x ½-inch eccentric	Tellable

Tapped right hand	Temperate
Tapped left hand	Temporal

Tapped for ¼-inch air valve	Tensive
Tapped for single pipe steam as per list	Termless
Tapped for double pipe steam as per list	Ternate
Tapped for top supply and bottom return on same end	Testate
Tapped for top supply and bottom return opposite ends	Testify
Tapped for both supply and return tappings at bottom	Tetrapod
Tapped regular as per list	Tetragon
Tapped for Paul System	Tetrate
Tapped for Webster System	Teucer
Tapped at "A"	Textural
Tapped at "B"	Theoretic
Tapped at "C"	Theurgic
Tapped at "D"	Thicken
Tapped at "E"	Thieving
Tapped at "F"	Thimble
Tapped at "G"	Thionic
Tapped at "H"	Thistle

Radiator Repairs

Supply Leg Section	Throbbing
Return Leg Section	Throng
Intermediate Section	Thrower
Bushings, 1½ inches R. H. by ½-inch Str. R. H.	Tickle
Bushings, 1½ inches R. H. by ¾-inch Str. R. H.	Tidal
Bushings, 1½ inches R. H. by 1-inch Str. R. H.	Tincture
Bushings, 1½ inches R. H. by 1¼-inches Str. R. H.	Tinsel
Bushings, 1½ inches L. H. by ½-inch Str. R. H.	Titrated
Bushings, 1½ inches L. H. by ¾-inch Str. R. H.	Toadstool
Bushings, 1½ inches L. H. by 1-inch Str. R. H.	Toast
Bushings, 1½ inches L. H. by 1¼ inches Str. R. H.	Tobacco
Bushings, 1½ inches R. H. by ½-inch Ecc. R. H.	Toboggan
Bushings, 1½ inches R. H. by ¾-inch Ecc. R. H.	Tcilless
Bushings, 1½ inches R. H. by 1-inch Ecc. R. H.	Tollable
Bushings, 1½ inches L. H. by ½-inch Ecc. R. H.	Torpidity
Bushings, 1½ inches L. H. by ¾-inch Ecc. R. H.	Tortoise
Bushings, 1½ inches L. H. by 1-inch Ecc. R. H.	Toucanet
Bushings, 2 inches R. H. by ½-inch Str. R. H.	Touchilly
Bushings, 2 inches R. H. by ¾-inch Str. R. H.	Toupee
Bushings, 2 inches R. H. by 1-inch Str. R. H.	Tourist
Bushings, 2 inches R. H. by 1¼ inches Str. R. H.	Tourney
Bushings, 2 inches R. H. by 1½ inches Str. R. H.	Tourte
Bushings, 2 inches R. H. by ½-inch Ecc. R. H.	Touter
Bushings, 2 inches R. H. by ¾-inch Ecc. R. H.	Towage
Bushings, 2 inches R. H. by 1-inch Ecc. R. H.	Towboat
Bushings, 2 inches R. H. by 1¼ inches Ecc. R. H.	Towel
Bushings, 2 inches R. H. by 1½ inches Ecc. R. H.	Towing
Plugs, 1½ inches R. H.	Townlet
Plugs, 1½ inches L. H.	Township
Nipples, No. 1 Malleable Iron	Toxaway
Nipples, No. 2 Malleable Iron	Toxine
Nipples, No. 3 Regular Malleable Iron	Toyish
Nipples, 1½ inches Wall Radiator Internal	Toywort
Nipples, 1½ inches Wall Radiator Hex	Trabal
Gaskets, 1½ inches Graphited	Trachea
Nuts, $\frac{5}{16}$-inch Capped Sleeve	Trachyte
Nuts, ⅜-inch Radiator Hex	Trackless
Plugs, ⅛-inch Air Vent	Tractor

UNITED STATES RADIATOR CORPORATION

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